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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CXII.—No. 2914.] *LONDON: FRIDAY, NOVEMBER 4, 1921.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 4d.

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See Advertisement last week, page 103.

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See page 17. 9108

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See their Illus. Advertisement, page 107, last week.
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BUILDERS of RAILWAY CARRIAGES & WAGONS.
MAKERS of WHEELS and AXLES of all kinds.
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Electric Lifts (UP TO 25 TONS.) 9026
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See Illustrated Advertisement Page 100, Jan. 28.

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Steam and Electric Cranes, EXCAVATORS, CRANE-NAVVIES, GRABS, CONCRETE-MIXERS, SHIPS' WINDLASSES, WINCHES, and DECK MACHINERY. 9264
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Stewarts and Lloyds, Ltd., Glasgow and Birmingham.
See Advertisement page 46. 9091

Machine and Engineering WORK of all descriptions undertaken for Manufacturers, Patentees, &c. Also repairs and renewals. Best work, moderate charges.—ROSSER & RUSSELL, LTD., Queen's Wharf, Hammersmith.
NEW PATENT ACT.—ROSSER & RUSSELL, LTD., are prepared to undertake the manufacture of articles at present made abroad, and will be pleased to hear from firms desiring such work executed. 9311

E. J. Davis, M.I.Mech.E., Gas Engines Inspected, Tested and Reported Upon. Over 25 years' experience. Tel.: 736 and 737 Stratford. Wire: "Rapidising, London." —Great Eastern Road, Stratford, E. 15. 1794

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London Office—12, Victoria Street, S.W.
MANUFACTURERS OF RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
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Makers of WHEELS and AXLES, RAILWAY PLANT. FORGINGS, SMITH WORK, IRON AND BRASS CASTINGS. PRESSED STEEL WORK OF ALL KINDS.
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Augustin-Normand
67, rue de Perrey—LE HAVRE (France). 3890
Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

Electric Cranes.
S. H. HEYWOOD & CO., LTD., REDDISH. 9026

The National Foremen's ASSOCIATION OF THE ENGINEERING AND ALLIED TRADES. (Registered under the Trade Union Act.)
An Association specially formed to look after the interests of Foremen on their Supervisory Capacity. F601
All communications to—H. W. REID, General Secretary. Head Offices—66, Belgrave Road Victoria, London, S.W.1.

S. Sokal, CHARTERED PATENT AGENT.
1, Great James Street, Bedford Row, London, W.C.1. T.N. 4515 Museum. 9075

For Continental Business. INTERNATIONAL CONSULTING ENGINEERS' OFFICE, 61-63, Bd. République, Versailles, FRANCE.

Royles Limited, ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM AND GAS KETTLES, Merrill's Patent TWIN STRAINERS for Pump Suctions. } ROWS PATENTS
SYPHONIA STEAM TRAPS, REDUCING VALVES
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YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

Matthew Paul & Co., Ltd. LEVENFORD WORKS, Dumbarton. 9518
See Full Page Advt., page 70, Oct. 14.

Forgings.
Walter Somers, Limited, HALESOWEN. 7116

Head, Wrightson & Co., LIMITED.
See Advertisement page 66. 2402

Taylor & Challen Presses 8104
About 200 NEW PRESSES in Stock in our Showrooms for immediate delivery at specially Reduced Prices.
TAYLOR & CHALLEN, LTD., Engineers, Constitution Hill, BIRMINGHAM.
See Full Page Advertisement page 66, Oct. 14.

FOR **Drop Forgings** write GARTSHERRIE ENGINEERING & FORGE CO., 50, Wellington Street, Glasgow. 9674

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Sole Makers: SPENCER-BONECOURT, LTD., 9283
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P. & W. MacLellan, Limited, CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF RAILWAY CARRIAGES AND WAGONS OF EVERY DESCRIPTION,
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 129, Trongate, GLASGOW. Od 3547
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Centrifugals.
Pott, Cassels & Williamson, MOTHERWELL, SCOTLAND. 9727
See half-page Advertisement, page 73, Oct. 28.

The Manchester Steam Users' Association.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, Mount Street, Manchester.

Chief Engineer: C. E. Stromeyer, M.I.C.E.

Founded 1854 by Sir William Fairbairn.

Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 9310

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B.Sc., Inst. C.E., I. Mech. E., all Engineering Exams. Special Courses and Single Subjects. Personal tuition.—For full particulars apply to Mr. Trevor W. Phillips, B.Sc. (Hons.), Assoc.M.Inst.C.E., M.R.S.I., etc., 8-10, Trafford Chambers, 58, South John Street, Liverpool. 9296

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and all Engineering Examinations.—Mr. G. P. Knowles, B.Sc., M.E.E., A.M.Inst.C.E., F.S.I., M.R.San.I., prepares candidates personally or by correspondence. Thousands of successes during the last sixteen years. Courses may commence at any time.—39, Victoria St., Westminster, S.W. Tel. 4780 Victoria. 9649

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TENDERS.

MANCHESTER CORPORATION GAS DEPARTMENT.

THE GAS COMMITTEE invite

Tenders for the Supply and

DELIVERY and ERECTING of THREE—3 TON OVERHEAD HAND TRAVELLING CRANES, required for the Mechanics' Shop, at the Bradford Road Works, Manchester.

Specification and Form of Tender may be obtained on application to Mr. Godfrey W. Kaye, Secretary, at the Gas Offices, Town Hall, Manchester.

Further particulars and other information required may be obtained on application to the Engineer, at his Office, Rochdale Road Works, Manchester.

Sealed Tenders, endorsed "Tender for Three—3 ton Overhead Cranes," addressed to the Chairman of the Gas Committee, must be delivered at the Gas Offices, Town Hall, Manchester, not later than Ten a.m. on Friday the 11th day of November, 1921.

The Gas Committee do not bind themselves to accept the lowest or any other Tender.

By Order,
THOMAS HUDSON,
Town Clerk.

Town Hall, Manchester,
October, 1921. S 452

MANCHESTER CORPORATION WATERWORKS,

THIRLMERE AQUEDUCT—FOURTH PIPE LINE.

WELDED STEEL PIPES, ETC., and CAST IRON SPECIAL PIPES, ETC.

The Waterworks Committee Invite

Tenders for the Supply of

WELDED STEEL PIPES, Etc., 54 inches diameter, as follows:—

Contract No.	1	...	About 6300 tons.
,,	2	...	,, 5300 tons.
,,	3	...	,, 3400 tons.
,,	4	...	,, 4400 tons.

Also for the SUPPLY of about 500 tons of CAST IRON SPECIAL PIPES, Etc., varying from 54 in. to 6 in. in diameter.

Specification, Form of Tender, etc., may be obtained on application to the SECRETARY, Waterworks Offices, Town Hall, Manchester, upon payment of a deposit of Five Guineas for each contract, which will be returned to the Tenderer provided that he shall have sent in a *bona fide* Tender and shall have returned the documents and the drawings lent to him, the drawings to be unmarked. Further information if required may be obtained from the Waterworks Engineer.

Sealed Tenders, endorsed as directed, must be delivered at the Waterworks Offices, Town Hall, Manchester, not later than first post on the 21st November, 1921.

By Order,
THOMAS HUDSON,
Town Clerk.

Town Hall, Manchester.
3rd November, 1921. S 476

LLANDAFF AND DINAS POWIS RURAL DISTRICT COUNCIL.

RHOOSE VILLAGE DRAINAGE.

TO CONTRACTORS.

The Council invite

Tenders for the Construction

of Certain Lengths of STONEWARE and IRON SEWERS of 9 inches in diameter, together with the necessary Manholes, Flushing Tanks and other Appurtenances.

The Contract also includes the Construction of a Sea Outfall, formed of 9 inch Cast-iron Pipes, laid through the rock foreshore in accordance with plans and specification prepared by Mr. G. Midgley Taylor, Civil Engineer.

Contractors desirous of tendering may obtain copies of the Specification, Bill of Quantities and Form of Tender, from the Offices of the Engineer, 36, Victoria Street, Westminster, S.W. 1, upon payment of £5 (cheque only), which will be returned upon receipt of a *bona fide* Tender. The drawings may be inspected either at the Offices of the Engineer, Westminster, or at the Office of the Surveyor to the Council, Mr. William Farrow, Park House, Cardiff.

Tenders endorsed "Rhoose Drainage," must be delivered in a sealed package addressed to the undersigned at his Offices, Cardiff, before Ten a.m. on Wednesday, the 16th day of November, 1921.

The Council do not bind themselves to accept the lowest or any Tender.

By Order,
M. WARREN,
Clerk to the Council.

Council Offices,
Park House,
20, Park Place,
Cardiff.
20th October, 1921. S 387

THE SOUTH INDIAN RAILWAY COMPANY, Limited, are prepared to receive

Tenders for the Supply of:—

1. CAST-IRON SLEEPERS (7,155 tons).
2. TIE BARS, GIBS and COTTERS (916 tons).
3. COILED STEEL KEYS (No. 182,437).

Specifications and Forms of Tender will be available at the Company's Offices, 91, Petty France, Westminster, S.W. 1, on and after to-day at Eleven a.m.

Tenders addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked:—"Tenders for Sleepers," or as the case may be, must be left with the undersigned not later than Noon on Friday, the 11th November, 1921.

The Directors do not bind themselves to accept the lowest or any Tender.

A charge, which will not be returned, will be made of 40s. for each copy of Specification No. 1, and 20s. for each copy of Specifications Nos. 2 and 3.

Copies of the Drawings may be obtained at the Office of Messrs. Robert White & Partners, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W. 1.

A. Muirhead, Managing Director.

91, Petty France, S.W. 1.
2nd November, 1921. S 510

LONDON COUNTY COUNCIL.

WANDLE VALLEY SEWER.

Tenders are Invited for a

BRICK and CONCRETE SEWER of varying sizes of a total length over all of nearly 2¼ miles, wholly situated in the Borough of Wandsworth.

Persons desiring to Tender may obtain on and after Friday, 4th November, 1921, the Specifications, Bills of Quantities, Form of Tender, etc., on application to the Chief Engineer at the County Hall, Spring Gardens, S.W., upon payment to the Cashier of the Council of the sum of £5. This amount will be returnable only if the tenderer shall have sent in a *bona fide* Tender and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the drawings, specification and other contract documents may be inspected at the County Hall before the payment of the fee.

No Tender received after twelve noon on Tuesday, 22nd November, 1921, will be considered.

The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk of the London County Council.
S 496

MANCHESTER CORPORATION GAS DEPARTMENT.

THE GAS COMMITTEE are prepared to receive

Tenders for the Supply,

DELIVERY and FIXING IN POSITION, of RAIL SLEEPERS, etc., on the Extensions to Elevated Coal Sidings; also WOOD BLOCK FLOORING to new Mechanics' Shop, at the Bradford Road Gas Works, Manchester.

Specification, Bill of Qualities and Form of Tender may be had on application to Mr. Godfrey W. Kaye, Secretary, Gas Department, Town Hall, Manchester.

Drawings may be seen, permission to view the Site, and any other information obtained on application to Mr. W. Newbiggine, Engineer, at his Office, 5, Norfolk Street, Manchester.

Sealed tenders in official envelope, addressed to the Chairman of the Gas Committee and endorsed "Rail Sleepers, etc., Bradford Road Station," to be delivered at the Gas Offices, Town Hall, Manchester, not later than Ten a.m., on Friday the 11th day of November, 1921.

The Gas Committee do not bind themselves to accept the lowest or any other Tender.

By Order,
THOMAS HUDSON,
Town Clerk.

Town Hall, Manchester,
October, 1921. S 451

METROPOLITAN WATER BOARD.

WALTON TO HONOR OAK MAIN.
Section No. 2.

TENDER FOR THE LAYING OF 48 in. MAIN, MALDEN TO CLAPHAM PARK.

The Metropolitan Water Board invite

Tenders for the Laying and

JOINTING of about 11,400 lin. yards of CAST IRON WATER MAIN, 48 inches in diameter, from Coombe Road, Malden, to Thornton Road, Clapham Park, in the Counties of Surrey and London, through public and private roads, fields, &c., together with contingent works.

Drawings, Conditions of Contract, and Specification, may be inspected without payment of fee at the Offices of the Board, Chief Engineer's Department (Room 201), New River Head, 173, Rosebery Avenue, Clerkenwell, E.C., on and after Monday, 14th November, 1921.

Forms of Tender, Conditions of Contract, Specification, Bills of Quantities, and Schedules of Prices, together with a spare copy of the Bills of Quantities and Schedules of Prices, may be obtained on and after the 14th November, 1921, from Mr. Henry B. Stilgoe, M.Inst.C.E., the Chief Engineer, on production of an official receipt for the sum of £20, which sum must be deposited with the Accountant to the Board at 173, Rosebery Avenue, Clerkenwell, E.C. 1, and will be returned on receipt of a *bona fide* Tender, together with all the above named documents (with the exception of the spare copy of the Bills of Quantities and Schedules of Prices, which may be retained by the Tenderer). Such payments and applications must be made between the hours of Ten a.m. and 4.30 p.m. (Saturdays Ten a.m. and Twelve noon).

Tenders, enclosed in sealed envelopes addressed to "The Clerk of the Board, Metropolitan Water Board, New River Head, 173, Rosebery Avenue, E.C. 1," and endorsed "Tender for Main, Walton to Honor Oak, Section No. 2," must be delivered at the Offices of the Board not later than Ten a.m. on Monday, 19th December, 1921.

The Board do not bind themselves to accept the lowest or any Tender.

W. MOON,
Clerk of the Board.

Offices of the Board,
New River Head,
173, Rosebery Avenue,
Clerkenwell, E.C. 1.
31st October, 1921. S 471

To Firms Wanting Work.—

QUOTATIONS are INVITED for MANUFACTURE of a SMALL REPETITION-PRODUCT comprising Steel and Iron Castings, etc., and Plain Machining.

Quantity is expected to reach a high figure and depends entirely upon sales demand, and a sliding scale must provide for prices in accordance with output. Acceptance depends entirely upon terms, and the advertiser does not bind himself to accept lowest or any Tender or Quotation.

Working drawings and particulars will be sent upon receipt of application and fee of £1 1s., which fee cannot under any circumstances be returned.

Applications to—

Mr. H. George Harley, S 487
Consulting Engineer, Grand Avenue, Camberley.

LONDON COUNTY COUNCIL.

Tenders are Invited for the

RECONSTRUCTION and WIDENING of PRIESTS BRIDGE, carrying Upper Richmond Road over the Beverley Brook.

Persons desiring to Tender may obtain the Specifications, Bills of Quantities, Form of Tender, Drawings, etc., on application to the Chief Engineer at the County Hall, Spring Gardens, S.W., upon payment to the Cashier of the Council of the sum of £3. This amount will be returnable only if the tenderer shall have sent in a BONA-FIDE Tender, and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the drawings, specification and other contract documents may be inspected at the County Hall before the payment of the fee.

No Tender received after Four p.m. on November 21st, 1921, will be considered.

The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk of the London County Council.
S 475

TO ELECTRICIANS AND OTHERS.

THE METROPOLITAN ASYLUMS BOARD invite

Tenders for the Installation of

ELECTRIC LIGHTING CABLES, etc. throughout the Training Ship, "Exmouth," off Grays' Essex, in accordance with drawing and specification prepared by Mr. T Copper, M.Inst. C.E., M.I.Mech.E., Engineer-in-Chief. The Drawing, Specification, and Form of Tender may be inspected at the Office of the Board, Embankment, E.C. 4, on and after Ten a.m. on Wednesday, November 2nd, and the Drawing, Specification and Form of Tender can then be obtained upon payment of a deposit of £1 in respect of the work. The amount of the deposit will be returned only after the receipt of a *bona-fide* Tender, sent in accordance with the instructions on the Form of Tender, and after the Specification and the Drawing have been returned.

Tenders, addressed as noted in the form, must be delivered at the Office of the Board not later than 2.30 p.m. on 23rd November, 1921.

(By Order) DUNCOMBE MANN,
Clerk to the Board. S 462

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to Noon on Friday, 25th November,

Tenders for the Supply of:—

1. MATERIAL for the construction of Bogie Carriages, etc.
2. PARTS for constructing Bogie Carriage Underframes, etc.
3. WHEELS AND AXLES.
4. LAMINATED BEARING SPRINGS.
5. HELICAL SPRINGS.

Tenders must be made on forms, copies of which, with Specification, can be obtained at these Offices on payment of 20/- each (which will not be returned). The Directors do not bind themselves to accept the lowest or any Tender.

S. G. S. YOUNG, Secretary.

Offices: The White Mansion,
91, Petty France,
Westminster, S.W. 1.
2nd November, 1921. S 511

APPOINTMENTS OPEN.

BOMBAY PORT TRUST.

The Trustees invite

Applications from Engineers

possessing experience in Port, Dock and Railway construction and maintenance for APPOINTMENT as their CHIEF ENGINEER.

The salary of the officer selected will be determined according to qualifications and experience.

Under the Trustees' rules married officers are provided with house accommodation, for which rent at the rate of 10 per cent. of salary is charged.

Applications should be addressed in writing to the Consulting Engineers and Agents, Bombay Port Trust, 2, Queen Anne's Gate, S.W., and will be received up to 1st December, 1921. They should be accompanied by a complete résumé of applicants, professional career and copies of not more than three recent testimonials.

Age (preferably between 40 and 45 years) should be stated.

By Order of the Trustees,
A. J. BARRY,
WALTER C. HUGHES,
K. A. WOLFE BARRY,
Consulting Engineers and Agents.

Dartmouth House,
2, Queen Anne's Gate,
Westminster, London.
28th October, 1921. S 454

Civil Engineer Re-

QUIRED by the Government of Hong Kong for three years' service as an Assistant Engineer in the Public Works Department, with prospect of permanency. Salary £400 a year, rising by annual increments of £30 to £600 a year with temporary addition of exchange allowance. Free passages provided.

Candidates, unmarried, 25 to 30 years of age, must be Associate Members of the Institute of Civil Engineers who have had experience on the construction of Waterworks and in the use of concrete. Preference will be given to candidates who have been trained in a Waterworks Engineer's Office.—Apply at once in writing, stating age and brief details of experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting M/Hong Kong 11,019. S 455

UNIVERSITY COLLEGE, CORK.

ASSISTANT IN ENGINEERING.

A Full-Time Assistant in

ENGINEERING is REQUIRED.

For particulars apply to—

JOSEPH DOWNEY,
Secretary.

S 418

TECHNICAL COLLEGE, BRADFORD.

Applications are Invited for

APPOINTMENT as HEAD of the DEPARTMENT of CIVIL ENGINEERING in the College.

A salary up to £700 per annum will be paid to a candidate of suitable qualifications and experience.

Full particulars of the appointment and forms of application may be obtained from the Principal of the College.

Applications to be returned so as to reach me as soon as possible.

N. L. FLEMING,
Town Clerk.

20th October, 1921. S 395

STAFFORDSHIRE EDUCATION COMMITTEE. INSTRUCTOR IN THE LOCK AND KEY INDUSTRY AND IN METAL-WORK.

A Skilled Artisan with some

scientific and technological training is REQUIRED. He will take classes at Willenhall for youths engaged in the Lock and Key industry, and he will also act as Metal-work Instructor for the Elementary Schools. He must hold a diploma in Metal-work recognised by the Board of Education, and must have had a good general workshop training. A salary of £300 per annum is offered. Forms of application, which should be returned not later than December 1st, may be obtained from the undersigned. S 486

GRAHAM BALFOUR, Director of Education.

County Education Offices, Stafford, November, 1921

Engineer for Cement Works.

—WANTED a CONSTRUCTIONAL and OPERATING ENGINEER in India, to superintend erection and maintenance of Cement Mill Machinery, Rotary Kilns and Power Plants. Salary offered up to Rs. 900 per month according to qualifications, with free quarters, light and fuel. Three years' agreement with first class passage out and home. Good prospects for suitable man.—Apply by letter only, with copies of testimonials, etc., to TATA, LIMITED, Capel House, New Broad Street, London, E.C. 2. S 412

Electrical Engineer Wanted

to take charge, under Chief Engineer, of all electrical equipment for a large Tinplate Mill in India. Applicants must have thorough knowledge of the maintenance and running of motors up to 1000 B.H.P. high tension and low tension A.C. Transformers, Switchgear, etc., also continuous current equipment and Transmission Lines. Age 30 to 35 years. State fully technical training and experience, salary required, and send copies of recent testimonials.—Apply, "Tinplate Electrical Engineer," BOX 1404, SHAW & BLAKE, Ltd., Advertising Agents, 37, Surrey Street, Strand, W.C. 2. S 477

Mechanical Engineer Wanted

to take charge, under Chief Engineer, of all machinery and plant for a large Tinplate Mill in India. Applicants must have thorough knowledge of maintenance and repairs of heavy rolling mills, boilers, pumps, hydraulic machinery, and the usual Tinmill plant. Age 30 to 35 years. State fully technical training and experience, salary required, and send copies of recent testimonials.—Apply, "Tinplate Engineer," BOX 1404, SHAW & BLAKE, Ltd., Advertising Agents, 37, Surrey Street, Strand, W.C. 2. S 478

Colliery Superintendent

ENGINEER REQUIRED for large Australian Collieries to work under General Manager. Must be thoroughly experienced in both steam and electrical plants as applied modern collieries. Experienced with coking and by-product plants an advantage. Only first class men will be considered. Applications and references in duplicate, stating experience, salary expected, age, and when at liberty, furnishing photo.—Address, S 514, Offices of Engineering.

Civil Engineer Required

for three years' service as an Assistant Engineer in the Public Works Department, Cyprus, with prospect of permanency. Salary £360 a year, rising by annual increments of £30 to £500 a year. Quarters not provided. Free passages. Candidates, unmarried, under 35 years of age, must have a good knowledge of draughtsmanship, building and road work, and preferably have passed the A.M.I.C.E. examination, or that of the Institute of Municipal and County Engineers. Apply at once, in writing, giving age and brief details of experience to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W.1, quoting M/Cyprus 11167. S 501

Chief Vehicle Inspector

REQUIRED by Argentine Railway. Age about 30. Must have served time in Carriage and Wagon Works and have had good English Railway experience. Salary about £450, free passage and 3 years' agreement. Write with full details, education, training experience, age, &c., and copies testimonials to BOX "ROBO," c/o DAVIES & CO., 95, Bishopsgate, E.C. 2. S 490

Wanted, Expert Salesmen in

all districts, well introduced amongst engineers, architects, etc., to sell direct highest grade Fire Extinguishers. Commission basis only. State fullest particulars.—Address, S 448, Offices of Engineering.

Scale Tester (Expert) Wanted,

for large Factory (Essex, Tilbury Line). All-round experience essential, including oil-tank, railway and other weighbridges and machines. Write, full particulars of experience, age, and salary required to "SCALE" c/o Street's, 30, Cornhill, E.C. 3. S 499

Leading Draughtsman

WANTED, accustomed to Uniflow Engine design. State experience, age and salary.—Address, S 450, Offices of Engineering.

THE NEW WINNIPEG WATERWORKS.

By Frank W. Skinner, M.Am.Soc.C.E.

(*Concluded from page* 591.)

Arch Design.—The principal considerations determining the design of the aqueduct arch included type of foundation; economy of materials; character of soil for support; chemical action; backfilling; position of ground water-level; depth of penetration of frost; range of temperature of water in aqueduct; rapidity of construction; and construction methods.

As a settlement of $\frac{1}{16}$ in. would crack the invert it was required that the foundations should be especially rigid. It was assumed that the concrete weighed 140 lb. per cubic foot and that the arch supported backfill 4 ft. deep, that weighed 100 lb. per cubic foot. Stresses were computed for earth pressures varying in direction from vertical at the top, to a slope of 23 deg. from vertical at the bottom; interior water pressures were assumed to be radial, and exterior water pressures to be normal to the outer surfaces. The intrados and extrados of the arch were determined by making the line of force fall within the middle third of the section, thus assuring the absence of any tensile stress there.

The arch was reinforced only under railroad and highway crossings and under the Brokenhead Slough where the backfill was very light and the internal pressure tended to produce deformation of the structure. Although the temperature falls sometimes to 50 deg. below zero and the frost penetrates to a depth of 4 ft. or more below the surface of the ground the temperature of the air in the aqueduct a short distance from open manholes was never lower than about 35 deg.

It was found that frost penetrated most deeply and quickly through moist dense clay, less deeply and quickly through sand and gravel, and slowest through partly dried muskeag covering. In most places it did not penetrate the backfill to the arch until spring and then showed only as hoar frost in patches, although in some cases the earth above the arch was frozen and arched upward leaving wide cracks over the aqueduct.

In general the aqueduct was considered as a lining and cover for a ditch through which the water flows without exerting pressure, and a large construction economy was effected by selecting a light construction known to be liable to cracks that were not serious and could be repaired at an expense far below that of building a structure that would be sure not to crack. The great importance of this decision is shown by the fact that if the arch and invert had been made just 1 in. thicker than they are, they would have required about 35,000 yards more concrete at a total extra cost of about 500,000 dols. All of the cut and cover sections of the aqueduct that are easily accessible and where cracks may occur without damage and may be easily repaired, have a horseshoe shape cross-section and have no reinforcement. The stresses and bearing loads are indicated in the cross-section given in Fig. 3, on page 591 *ante*.

Pipe Section.—Only at the river crossings, where the aqueduct was subject to internal pressure, was the concrete reinforced, and in these places it was given a circular cross-section and proportioned so that the concrete should not receive more than a maximum compression of 500 lb. per square inch, and the steel a tension of not more than 10,000 lb. per square inch; limits that were established to prevent the possibility of development of hair cracks. This was considered to be conservative practice and to afford complete protection against the penetration of water that might cause the steel to rust and by the attendant expansion, burst or flake the concrete.

Surge Tank.—The aqueduct is subject to stresses occasioned by changes in the velocity of flow caused by sudden variations of draught, especially when the 50,000,000-gallon pumps at Red River shall be thrown suddenly into operation. It is calculated that the pumping will increase the velocity in the 5 ft. 6 in. pipe line from 1·7 ft. to 4 ft. per second and will cause a surge starting to rise from the lowest point 6 minutes and 20 seconds after the pumps are put in operation. As a protection against possible strains caused in this manner there has been provided a stand pipe, or surge tank, connected to the pressure pipes and overflows connected to the gravity flow sections. The reinforced concrete surge tank has a central receiving well 25 ft. in diameter concentric with a cylindrical shaft 32 ft. 6 in. in diameter, and provided with a concrete roof 9 ft. 8 in. above the overflow roof. Both these circular walls are carried on an annular concrete base 8 ft. thick, with a footing of I-beams enclosed in reinforced concrete, and supported on eight concrete foundation piers carried down to rock 24 ft. below the bottom of the surge tank. The structure is enclosed by an annular brick facing and an air jacket to protect it from frost. Overflow water is discharged through a 6-in. cast-iron pipe.

Overflows are provided at all important river crossings to prevent accidents to the arch section due to possible careless operation of the intake gate. They provide for an ample overflow, and are equipped with a blow-out valve; stop logs to regulate the depth of flow in the aqueduct; boat entrances for inspection purposes; an overflow channel to the river, trapped to exclude cold outside air; and arrangements for balancing variations of the air pressure in the aqueduct due to changing depth of flow. The upper end of the overflow is contained in a protecting house that covers the top of the aqueduct and the connection of the overflow to the opening in the upper part of the aqueduct arch. There is a screen installed at the top of the overflow which is through a concrete conduit provided with a simple trap in which a water seal is constantly maintained to exclude the exterior air from the aqueduct.

Culverts.—Excepting the important river crossings all of the surface drainage crossing the line of the aqueduct is carried under the aqueduct through concrete culverts of a uniform type, designed to be frost proof except at the open mouths that can be easily freed from ice that may form there in very cold weather. These culverts are concrete conduits with a horizontal section under the aqueduct connecting with upwardly-inclined sections at each end to the open trench, with walled approaches. Both inlets and outlets are provided with stop logs for the exclusion of water if necessary, and the entrances are guarded by heavy chains to keep out cattle and large wild animals. A drop in the culvert is sufficient to provide an automatic water seal preventing a circulation of cold air that might hurt the aqueduct above it.

Foundation Conditions.—The aqueduct and its appurtenances were largely located in a soil consisting of boulder clay, hardpan, gravel and rock, or in soft soil on top of such strata. An important exception, however, is 20 miles of clayey soil containing no silt or granular material, but underlaid with a layer of gravel and boulders resting on limestone rock 40 ft. or more below the surface.

This soil is very treacherous and uncertain and its compressibility varies with the depth below the surface and the water content. Cracks, produced by drying out of the soil in summer, often extend to a depth of several feet and, becoming filled with water, tend to make the lower strata semi-fluid. Often the dry hard surface, many feet thick, rests on a lower saturated stratum. Tests made on the surface of an excavation that has been dry for a day or two may give high-bearing values although the same soil under other moisture conditions will flow under pressure. The worst feature of this soil is its progressive continuous settlement under a constant load, and the relatively greater settlement at small depths than at larger depths.

A series of tests showed that at a depth of 4 ft. to 7 ft. below the natural surface the total settlement under a load of 3,000 lb. per square foot amounted to 0·023, 0·027 and 0·017 at the end of the first day, and 0·032, 0·035 and 0·21 at the end of the thirteenth day, while under load of 6,000 lb. per square inch the corresponding settlements were 0·77, 0·076 and 0·030 at the end of the first day and 0·103, 0·108, 0·086 and 0·037 at the end of the thirteenth day. An analysis of the tests indicated that doubling the load per square foot at a depth of 4 ft. caused $3\frac{1}{4}$ times the settlement; doubling the load at 5 ft., $2\frac{1}{2}$ times the settlement; and doubling it at 7 ft., $1\frac{3}{4}$ times the original settlement. For all loads the settlement at the end of two weeks was about $1\frac{1}{4}$ times the amount at the end of the first day. When the soil was dry the surface was as hard as a good road that could be marked by the heel only with difficulty.

On such soil settlements were bound to occur, and the design recognised this and was calculated to make them uniform. Troubles from settlement have, however, occurred only in about 1·6 miles of the 20 miles of aqueduct constructed on good soil, and only on about 1·05 miles of a total of about 65 miles have cracks appeared in other parts of the aqueduct line up to the time when the last inspection was made.

None of the cracked work had to be taken out or replaced. Most of it was repaired by cutting out the cracks to a width of half an inch and a depth of 2 in., cleaning them thoroughly and filling with cement mortar, caulked with a hammer. This made a very tight joint generally stronger than the old concrete. The actual cost of repairing the cracks amounted to less than half a dollar per foot of the length of aqueduct and repairs amounted to only about 3,500 dols. in all. A 270-ft. section of the most seriously damaged part of the aqueduct, in which the cracks had been repaired, was bulkheaded and tested and found to have a leakage of less than 5,000 gallons per mile per day, which would be a moderate amount even for a cast-iron pipe with caulked joints. The average of other tests showed a leakage of only about one-third of this amount.

Construction Railroads.—The line of the aqueduct was largely through a remote and somewhat inaccessible and uninhabited region which, for 56 miles, was virgin swamp land with no highways available for transportation of construction materials. The commission therefore determined to expedite the work, secure uniformity and co-ordination, make the contract more attractive to bidders and considerably reduce the total cost, by the construction from its own resources of a standard gauge railroad line with numerous sidings, closely paralleling the full length of the aqueduct and providing for the prompt and economical delivery of men, equipment and materials whenever and wherever required.

In the swamps much of the road bed was carried on cross poles, logs and brush, covered with dirt and heavily ballasted, some of which required much filling to prevent frequent derailment. The aqueduct right-of-way was from 300 ft. to 500 ft. wide, the unusual width providing for the necessity encountered in some places of very wide slopes in the cuts where landslides sometimes made it necessary to remove the excavated material to a distance of 150 ft. The deepest aqueduct cut was 23 ft. The railroad grade was built up entirely from side borrow pits which for several miles in one locality consisted of nothing but peat. Abundance of gravel was found and thorough surface drainage was provided. The tracks were laid with 90-lb. steel rails. The road was built in nine consecutive months at a cost of a little less than 1,500,000 dols. or about 13,100 dols. per mile of track.

The construction of the railroad was amply justified by the traffic that it carried during the building of the aqueduct which amounted to about 1,000,000 cub. yards of sand and gravel, for concrete making, 600,000 barrels of Portland cement, 500,000 yards of foundation material and backfill and various other materials that were transported. In addition there were three mixed trains every week for the transportation of contractors' plant and equipment, and reinforced steel, besides occasional special service.

Co-ordination of Design and Construction.—When the contracts were awarded, the direction of the work was put in charge of an experienced chief engineer and competent staff, and a very thorough supervision of the construction work was maintained by the consulting engineer, who spent a large amount of time in the field. Thorough co-operation was thus secured between the owners, the engineers' department, and the various contracts which were always handled for the best interests to the city and often to the advantage of the contractor without in any way impairing the quality of the work, or assuming any of the responsibilities of the contractors, or interfering with their freedom. Concessions were made and extra-contract services

were rendered that offset others and improved or simplified the work. Extra expense was avoided and uniform quality maintained by the city's provisions for furnishing sand, broken stone and cement to all the contractors, thus eliminating the delay and expense of establishing duplicate plants or employing middlemen.

The engineering department prepared an advanced schedule of all progress and operation and compared it with weekly reports, methods, progress and conditions of construction which showed if the contractor was on time. If not he was penalised, but the penalty was refunded to him after he had caught up with the schedule. The engineering department was also posted in advance as to all future requirements and supplies and made arrangements for the delivery of local plant and materials on or before the date needed, thus largely eliminating unnecessary delays and preventing interference between simultaneous and successive operations.

Falcon River Dike.—The Falcon river dike is an earth embankment about a mile long, 10 ft. wide at the top and 14 ft. in maximum height, built on the sandy bottom across the end of Indian Bay to divert the flow of water through a canal to Snow Shoe Bay and avoid the discoloration of the Winnipeg water supply. It is built of sand and gravel, excavated by steam shovels from a borrow pit a few hundred feet from the north end of the dike and delivered by four-yard dump cars hauled by dinky steam engines. Most of the dike was built by the use of a large wooden scow advancing with the embankment and connected to its forward end by stringers carrying the track on which the dump cars were pushed and emptied, thus building the dike from end to end. The 1 on 2 slope on the east base of the dike was heavily ripraped with stone quarried near by.

Fig. 10. Making Sand and Gravel Foundation for Invert.

Fig. 11. Delivering Concrete from Dump Cars.

Excavation, Methods and Plant.—The total earth excavation and backfill amounted to about 7,500,000 yards and rock excavation to about 16,000 yards. The maximum and minimum depths of cut were 23 ft. and 6 ft., the average depth being little more than 6 ft. The side slopes were generally 1 : 1½. The excavated material generally consisted of clay, sand, and peat and approximate proportions of one-half clay, one-third peat and one-sixth sand. Where the ground was swampy, for about 47 miles at the upper end of the aqueduct, the excavation was chiefly made with specially designed self-propelling drag-line machines mounted on rollers operated on timber mats built in sections, to distribute the load over the soft swampy soil. The booms were 50 to 110 ft. long and from them buckets of ⅜-yard to 3½ yards capacity were operated, both or excavation and backfilling.

In some cases the drag-line machines were supplemented by ordinary steam shovels and for a distance of about 18 miles where the cut was generally shallow and the soil firm, walking dredges were used. These machines had a long boom with an excavating bucket for digging the soil, and deposited it in spoil banks alongside the excavation convenient for returning it for backfilling. The machine platforms were braced by longitudinal trusses on each side carrying pivoted pedestals that could be swung back and forth and the weight of the machine transferred from them to inbound bearings, and back again alternately, enabling the machine to proceed very easily and rapidly by this reciprocating motion that involved no locomotive gearing or track construction.

Considerable advantage was derived by dumping the spoil close to the trench so as to form an elevated grade for a dinky railway service track independent of the standard gauge construction line, that was used for the distribution of the mixed concrete. After the building of the aqueduct arch, and the removal of the track the embankment was easily moved into the trench for backfill. The western or lower end of the aqueduct trench was excavated mostly by steam shovels of standard types and with buckets of 1 yard to 3 yards capacity. The machine excavation was limited to an elevation 6 in. above the required floor grade, below which the earth was removed to sub-grade by hand. The excavation was made according to the convenience of the contractor, to sometimes extend beyond the neat line, but was paid for only up to a slope of one horizontal on three vertical in firm soil, and to a slope of one horizontal on one vertical in dry sandy soil that would not stand on steep slopes. None of the aqueduct was on embankment, and none of the excavated material not used for backfill was required to be removed from the right of way, so that little filling of earth was required except where sand was excavated in borrow pits and transferred to places where it was necessary to reinforce the soft bottom of the trench, this necessitating at times a haul of a maximum length of about 30 miles.

The efficiency of the excavating machinery is indicated by the average amount handled per 10-hour day by the different machines. The steam shovel with a 1¼-yard dipper made a 12-foot cut in clay at the rate of 612 yards per day. The walking dredge with a 1-yard dipper made an 8-ft. cut in clay at the rate of 745 yards. The drag-line machine with a 1-yard bucket made a 7½-foot cut of 1 foot to top soil and 6½ foot of fine wet sand at the rate of 740 yards, per day. With 2-yard bucket in a 9-foot cut through 2 ft. of peat, 3 ft. of fine sand and 4 ft. of gravel, 900 yards. With 2-yard bucket in a 14-foot cut through 12 ft. of peat and 2 ft. bottom clay, 1,950 yards. With a 2½-yard bucket in an 18½-foot cut through 6 ft. of peat and 12½ of clay, 2,920 yards, per day.

Drainage.—As all of the trench grade lies below ground water level, seepage was heavy and large quantities of water amounting perhaps to a maximum of 500,000 gallons in 24 hours in most of the separate excavations, was encountered, but was all removed in compliance with the requirements that the ground water level should be lowered below the grade of the trench floor. This was accomplished by side wall trench drains and a surface depressed drain lined wooden box and transverse cover slats surrounded by coarse gravel or broken stone. These discharged at intervals of 100 ft. or more into sumps carried down 2 ft. or 3 ft. below subgrade and emptied by diaphragm pumps operated by gasolene motors. These were mounted on small trucks and easily shifted from sump to sump as the work advanced.

Foundation.—The preparation of the subgrade to receive the heavy aqueduct load varied according to the character of the soil. In rock and hard soil it required only excavating and trimming to the required line, or if necessary, levelling up of any irregularities and depression. Where the bottom was of soupy clay it was made by a fill of broken stone of various sizes chiefly one-man pieces. Quicksand was excavated below subgrade chiefly between lines of wooden sheet piling and the bottom was covered with stone and gravel supporting a box drain around which the trench was levelled up with broken stone that was kept dry and provided satisfactory foundation for the concrete invert.

Wherever peat was encountered it was excavated down to the bottom of the deposit and the trench was backfilled up to about 2 ft. above grade with sand and gravel deposited under water. This was afterwards underdrained and settled and when trimmed to the proper lines provided a strong and satisfactory foundation. Unstable clay was excavated to an increased width where wider and reinforced foundations, and in some instances piles, were installed to support the invert. In such cases great care was taken in backfilling to prevent transmission of irregular pressures to the aqueduct.

In some cases where the surface of the clay soil was intersected by deep and wide cracks water penetrated below subgrade, making the clay semi-fluid and greatly impairing its bearing capacity, even though it might appear solid when first exposed after it had been dried. To avoid the expense of deep excavations in these places the excavation was sometimes made far enough below subgrade to permit the clay to be covered by a thick layer of sand and gravel deposited under water. Subsequently sumps were sunk close together and being pumped out drained the bottom of the trench from the top downward, eventually producing a bottom so dense that it required a pickaxe to remove, and stable enough to endure the load of the finished aqueduct and conduit without settlement. A view showing the making of a sand and gravel foundation is given in Fig. 10 annexed.

Aggregate.—On the recommendation of, and under the direction of the consulting engineer,

satisfactory sand and gravel pits were located. The materials were excavated by steam shovels and delivered in dump cars to the screening and mixing plant and thence hauled and dumped, properly mixed, on the platforms of the contractors for making concrete. Careful tests were made of the concrete mixed with this aggregate and the required proportion of Portland cement, and it was found that with a well graded aggregate a product was obtained that was waterproof under a pressure head of 80 lbs. per sq. in.

Near the Red River crossing, where the aqueduct is laid with a 66-in. reinforced concrete pipe under pressure, installed in a trench about 16 ft. deep, the contract allowed payment only for excavation between vertical lines, and the contractors facilitated the excavation and eliminated the sloping sides by driving in advance a row of wooden piles from 2 ft. to 4 ft. apart on each side of the trench, and on them supporting the steam shovel with which the excavation was made. The rows of piles also retained the beam on which the heavy pipe laying machine was subsequently installed, and after the pipe was laid, the piles were drawn and re-driven in advance.

Concrete Mixing.—The aggregate, derived from broken stone crushed at the central plant and from the district's gravel pits, was distributed over the construction railroad as required to the different contractors, and was generally mixed in small portable machines mounted on cars moving on tracks alongside the trench and delivering directly to the required position. In some cases, however, central mixing plants were established and the concrete was delivered then to side dump cars that distributed it along the line of the aqueduct. This is shown in Fig. 11 on page 622.

Ordinarily the aggregate weighed about 112 lbs. per cubic foot dry or 125 lbs. with about 4 per cent. of moisture. Great pains were taken to secure, in sizes of aggregate, proportions that would insure very dense concrete and water tightness with the minimum proportion of cement. Ordinarily about 29 cub. ft. of aggregate were required for 1 cub. yard of concrete in place, allowing for all waste. The concrete for the pressure pipes was generally proportioned $1 : 1\frac{1}{2} : 2\frac{1}{2}$ of gravel not more than $1\frac{1}{2}$ in. in diameter and required about two barrels of cement per cubic yard. For the 85 miles of horseshoe shape aqueduct the proportion was about $1\frac{1}{4}$ barrels of cement per cubic yard of concrete. The Canadian barrel holds 350 lbs. of cement.

Concreting.—Usually the invert was concreted in alternate full width sections 15 ft. long, with the intermediate sections concreted after the first sections had hardened. The concrete was deposited on the carefully cleaned sub-grade, tamped, reinforcements made if required, and the upper surface screeded to template, floated and trowelled to provide a very smooth surface for the water flow. A thin horizontal longitudinal wooden strip was set continuously in the top of the invert at each side, projecting above the surface of the concrete to engage with the concrete later placed in the arch and side walls. Before it was hardened the concrete in the shoulders of the invert was cleaned

Fig. 12. Steel Form for Arch.

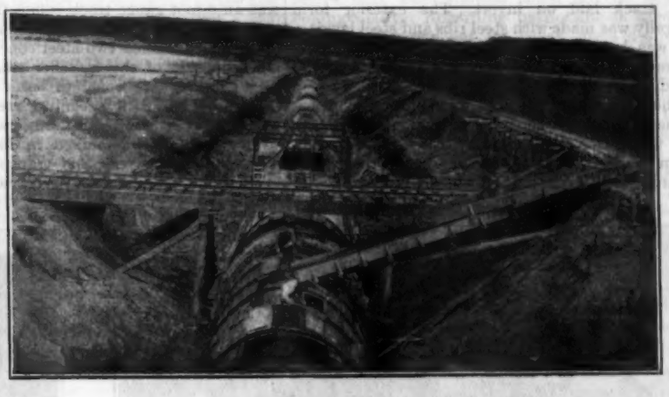


Fig. 13. Pouring Arch through Spout.

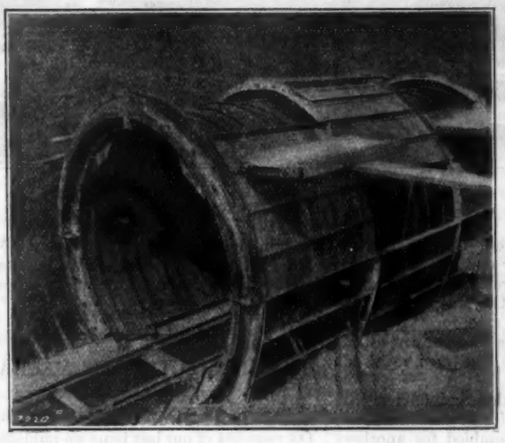


Fig. 14. Form in Place ready for Pouring.

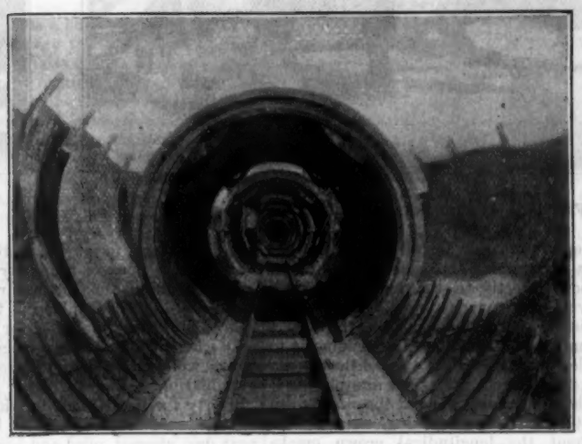


Fig. 15. Arch at Mile 16.

Fig. 16. View at Mile 24.

with wire brushes, removing all dirt and laitance and exposing the pebbles.

The arch and side walls were concreted in one continuous operation in sections about 45 ft. long. The inner form usually had a collapsible steel frame covered with steel lagging and supported on an adjustable steel traveller moving on a 6-foot gauge light track laid on invert. The exterior form generally was made with steel ribs and steel lagging, and was handled by the gantry traveller moving on track rails laid on the berms alongside of the aqueduct, as shown in Fig. 12.

Where the top of the arch was below the surface of the ground, the concrete was spouted directly from the mixer or distributing car to position as shown in Fig. 13, but when, as usual, the top of the arch was above the surface of the ground, the concrete mixer was generally installed in an elevated position on a car running alongside at a sufficient height to spout directly to the form. In some cases, however, the concrete was elevated in a movable hoisting tower and spouted through a flexible system of movable chutes conveying it to a considerable distance from the base of the tower.

By mixing the concrete rather wet and placing it carefully in the form adding more at the crown until it was too stiff for further working, an arch was secured without the longitudinal crown cracks likely to occur in arch construction when the crown is thin and flat. Other views of the aqueduct and forms are given in Figs. 14 to 16.

Backfilling.—Where the trench was wholly in swamp or muskeag, sand and gravel were imported and filled in up to the top of the arch, but in all other cases the backfill was of earth, thoroughly tamped to a depth of 4 ft. Above this elevation the backfill was completed to a height of 4 or 5 ft. above the crown, generally being placed by the machine used for its excavation.

The minimum top width of the backfill was 8 ft., and the side slopes were 1 vertical to 1½ horizontal. They were dressed by template and were heavily sown with grass.

Pipe Manufacture.—About 10 miles of the aqueduct is a reinforced concrete pipe, 5½ ft. in diameter inside, with walls 8 in. thick subjected to a working pressure of about 30 lbs. per square inch. The pipe was manufactured for the contractor at a central yard about 1 mile from the aqueduct and cost, when laid in the trench, about 1,850,000 dols. The pipe was laid in sections 8 ft. long with nut and spigot joints formed in the thickness of the wall. It is reinforced with triangular wire mesh fabric 2 in. from the inner surface and with circumferential ½ to ⅝ in. twisted steel rods wired to longitudinal bars 2 in. from the outer surface. The assembling of the reinforcement is shown in Fig. 17. The concrete is so dense that when the finished pipes were subjected to a pressure above the working requirements the seepage through the joints and pipe walls was less than that of a corresponding cast iron pipe line.

Pipe Casting.—The pipe casting yard at Transcoma was about 500 ft. wide and 3,500 ft. long. It was equipped with two standard gauge longitudinal surface tracks 300 ft. apart that connected at one end with the main line railroad and at the other end with the construction railroad for the aqueduct, and served as shipping tracks and for loading the heavy pipes. Concentric with the shipping tracks on the longitudinal axis of the yard was an 8-foot gauge track connecting the duplicate mixing plants at opposite ends of the yard, and on it were installed two steel concreting travellers. On each side of the traveller tracks there was a single line of 144 concrete bases for pipe forms, each provided with a central steam supply surrounded by several vertical outlets.

The concrete was mixed in four machines at each end of the yard and transported in conical buckets one on each side of the traveller, overhanging the line of steel forms which were filled by a small valve at the apex of the lower end of the bucket. The wire mesh and the bar reinforcements were bent, wired, and assembled at the pipe yard. The collapsible interior and exterior steel forms engaged cast iron top and bottom rings and supported on top a working platform where two men received and distributed the concrete.

Thirty-six forms were provided and 36 lengths of pipe were cast daily. The forms were stripped next day, cleaned, oiled and assembled for another set, and the stripped pipes were allowed to remain on their bases for four days before being removed to storage. Each of the two travellers was operated by a crew of 10 men who simultaneously filled two forms, one on each side of the traveller. Some of the outer forms are shown in Fig. 18.

As soon as the pipes were stripped they were covered with canvass bags, and subjected to steam delivered through the base outlets and maintained for from 24 to 72 hours to expedite the setting and prevent freezing during the winter season, thus allowing the work to be safely carried on when the temperature was below zero.

The pipes were handled with a sling made with a semi-circular flat steel band with the two ends connected by a chain or wire rope attached to one end, passing around a sheave connected to the other end and thence to the hoisting tackle so that tension on it caused the hand to grip the pipe securely. This device was used for lifting the pipes, turning them to horizontal position on the storage skids and for loading them on cars and unloading them alongside the aqueduct trench. As the pipes were seasoned on the storage skids they were kept moist by frequent spraying.

Locomotive cranes unloaded the pipes from the flat cars on the construction railway, and transferred them to cars on the contractors service tracks that carried them above the trench to the place where they required. There they were unloaded by another locomotive crane with caterpillar traction moving between the track and the trench from 14 ft. to 16 ft. wide and about 8 ft. deep.

The pipe was lowered in the trench near the required position and received on the adjustable horizontal cantilever projection of a special car running on the track in the bottom of the trench. This car put the pipe in position and entered the joint and lowered it to bearing on a carefully levelled bed of gravel backfill over which concrete was poured to make the permanent cradle extending up to the spring line. Above this level the trench was eventually backfilled with earth.

The outside of the joints were pointed before the trench was backfilled, and the joints were grouted at a maximum rate of 240 linear feet of pipe in one 10-hour shift.

Temperature.—Careful observations made after the completion of the aqueduct and while it has been in service, show that there is scarcely any change in temperature of the water passing through the 100 miles of aqueduct, so that it is substantially the same in the city reservoir as at the source. The minimum temperature of about 35·5 deg. F. is reached in December and is maintained until March, after which it gradually rises to 72·5 deg. in July or August.

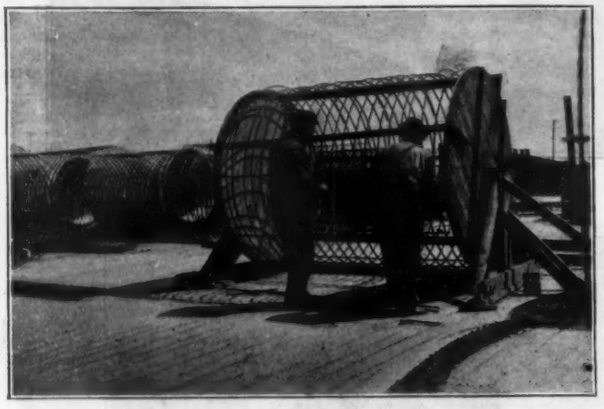


Fig. 17. Assembling Reinforcement for Pipes.

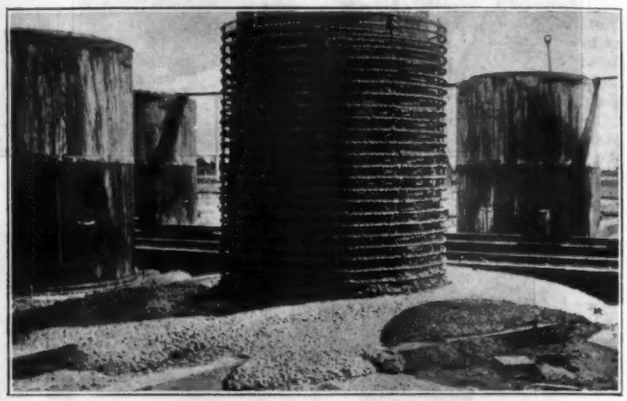


Fig. 18. Outer Forms for Pipes.

THE INSTITUTION OF MECHANICAL ENGINEERS.

Some Alloys of Aluminium.

On page 594 of our last issue we published a report of the proceedings of the above Institution at the meeting held on Friday, the 21st ultimo. That meeting was adjourned until Friday, the 28th ultimo, when discussion was resumed of the Eleventh Report of the Alloys Research Committee on Some Alloys of Aluminium (Light Alloys), by Dr. Walter Rosenhain, Mr. Sydney L. Archbutt, and Dr. D. Hanson, of the National Physical Laboratory, Teddington. We commenced the reprinting of a Summary of this Report on page 613 of our last issue, and conclude it on page 644 of the present issue.

On Friday last Engineer Vice-Admiral Sir George Goodwin, K.C.B., opened the adjourned discussion. Though unfortunately not present at the opening discussion, he endorsed both personally, and as President of the Institute of Metals, everything that Professor Turner had said in appreciation of the work involved in the report under discussion. The report covered a very wide field, and was written in plain language, such as could be understood by the engineer—no small feat for metallurgists—and it explained many of the puzzles which had hitherto been associated with the alloys of aluminium, while it pointed the way to a more extended use of the alloys; indeed, he hoped that one of its effects would be to remove doubts and stimulate application of these alloys. He wished first to refer to the subject of casting aluminium alloys. Although much information was given in the Summary regarding casting, he thought that unless the full report gave further information, the data were somewhat incomplete. He had seen a good deal of cast aluminium alloys, and had always found many failures. It was certain that the difficulties could be overcome, since in some establishments where such castings were made it was exceptional to get

a bad one, while in others a large proportion was bad. There must be a reason, and it would be a great help if it could be stated how the difficulties were to be avoided.

With regard to the point as to whether aluminium pistons were used for their higher thermal conductivity, or on account of their low weight, he thought that aluminium pistons had been introduced into the larger engines for one reason only—*i.e.*, the reduced weights of the reciprocating parts. Indeed, in those engines it was difficult to take full advantage of high thermal conductivity, however desirable. The alloy used for engine pistons in the Navy agreed, as the Admiral Dixon had previously said, very closely with the "Y" alloy mentioned in the report, and had proved quite satisfactory. Opportunely, a word had been received that day from two submarines on which such pistons were used, saying that everything was working splendidly. That was gratifying to the Admiralty, and doubtless also to the authors of the report. The report expressed the hope that aluminium alloys would be applied to the working parts of engines. Presumably that remark was based on the hope that weight would be reduced. It would be important, however, when introducing a lighter alloy (necessarily of larger scantlings) to see that the over-all weight was not increased. If the diameter of the crank-shaft, say, were increased, although the shaft might be lighter, all parts of the engine would be spread out—casings, bearings, frames, &c.—and the weight of those parts would be much increased.

He thought the term "ageing" was not well chosen, as it was customary to associate ageing with reduction of quality; "age-hardening," of course, a phrase used in the report, was more understandable. The authors had pointed to certain potential effects which resulted from annealing, and the same substances had been mentioned as both entering into and going out of the alloy. Did that imply that "ageing" was a process which, although similar, was yet the reverse of annealing? If so, he would expect, with castings of intricate form and unequal section, results resembling what would happen when such castings were annealed. He had no experience of annealing aluminium castings, but in the case of steel, annealing frequently produced warping. It was stated by the authors that some of the castings would age sufficiently in a few days, while others would take months. He was not aware of any engineering shop which could afford to wait months or years while castings were ageing. Ageing was the one thing in the report which troubled him. If a casting aged, then a part which was put into a finished engine would, presumably, also age, and if the casting would distort so would the finished part.

Professor H. C. H. Carpenter, F.R.S., thought that at many points of interest the authors seemed to put a curb upon their metallurgical imagination. From the metallurgist's point of view there were many things which were of deep interest, though hardly suitable for discussion before the Institution. While he thought the authors quite capable of taking care of themselves in their reply, he believed Sir George Goodwin had slightly misunderstood the situation. What the authors had said was, in effect, that many of the alloys "as cast" were in a sound and stable condition, and that they underwent a change which was nearly always in the direction of a slight stiffening, as measured by the tensile and ductility tests. They suggested that the phenomenon might be analogous to the age-hardening of "Duralumin," and certain other alloys which followed quenching, after a period of four or five days. He would, however, like to ask whether the authors really considered that at the ordinary temperature there was a segregation of the new phase in what they had called the "dispersed form" taking place at ordinary temperature. They stated that in one case the improvement amounted to only 8 per cent.; that was in a test piece cast to shape, which originally had a somewhat higher tensile strength than the alloys cast in thicker section and machined. He could not quite follow the authors when they stated that the fact that subsequent ageing did not improve the results to the same extent as in the case of those obtained with the thicker castings, suggested that the rate of cooling of the thinner pieces had been such as to bring the material already into a condition approximating to that which it would otherwise have attained as a result of ageing. He thought in the section which had been cast to shape, and which had, in a sense, been chilled or suddenly cooled, the alloy was placed in a condition further from that in which it would be after the deposition of the new phase. He would therefore have expected a still more perceptible increase in age-hardening.

He would like to suggest that the slight stiffening of the alloy—very slight and very slow—need not necessarily be due to separation of a new constituent in the particular dispersed form. If a metal were hardened cold and pressed, and then heat-treated at a comparatively low temperature—any temperature from 50 deg. to 100 deg. or 150 deg. C.—the first effect of heat was to cause a stiffening of the alloy, a rise in tenacity, and a slight fall in ductility. That was exactly what the authors had found with their alloys. In that case there was no question, apparently, of the separation of the new constituent or phase; the explanation must be a different one. The phenomenon was, he thought, due to the re-distribution of the strains in the work-hardened metal; but after that the alloy began to soften. The stiffening found by the authors might be of that nature, only at the ordinary temperature it would be much slower. He had made tests of work-hardened aluminium which had extended over four years. Duplicate specimens had been tested every year, and there was a very slow change taking place even at the ordinary temperature. He particularly admired the last section of the report, dealing with structural changes, and the authors' convincing proof that it was a separation of silicide of magnesium in a particular state which was really responsible for the age-hardening of the the alloys. Incidentally, at the National Physical Laboratory the Metallurgical Department was rendering a great service in tackling the working out of the ternary diagrams for such systems.

Sir Henry Fowler, K.B.E., would have liked more information with regard to the alloys which contained iron. There had been a period, he said, when there was an amount of aluminium available which contained iron, and a very great scarcity of the material free from it. Experiments had been made, particularly by Dr. Lea, in regard to the amount of iron which could be carried by the aluminium, and he believed it had been found dependent on the amount of copper; with 12 per cent. copper the permissible maximum of iron was 1 per cent.; with 4 per cent. of copper, 2½ per cent. of iron could be carried. Iron had the disadvantage that its shock resistance was low. It was a difficult metal to cast, and in conjunction with light alloys it drew very badly indeed, owing to the presence of Fe_2Al_5. With care in casting, a good result could be obtained by the employment of alloys with a certain amount of iron present. The metal mentioned in the report as L 11, which had been familiar to him as 711, containing seven parts of copper, one of zinc, and one of tin, was an excellent metal for casting. With regard to protection, he thought that if protection of the alloys were necessary, care should be taken to see that the right protection was given. He had had a tragical experience of a certain alloy which disintegrated owing, he believed, to the protective material taking the form of lead. He also thought the report had not referred at all to friction. Trouble always arose, for instance, when using an aluminium cylinder with an aluminium piston, while by using a steel cylinder the difficulty disappeared; so also by the use of an aluminium cylinder with cast iron. Professor Goodman had done good work in relation to this matter, but, unfortunately, nothing satisfactory had resulted.

Mr. J. B. Hoblyn said the report opened up a wide field for the correlation of design and metallurgy, but if full use were to be made of the alloys in constructional design, it was necessary to start with sound material supplied on a commercial basis. The discussion had been somewhat academic. His firm had, in connection with motor car building, endeavoured to secure a few of the alloys mentioned. They had asked for the "Y" alloy, that with a 21-ton maximum strength and 6·5 per cent. elongation, but had been unable to obtain it. They had also asked for the 20 zinc and 3 copper, in rolled sheet 17 ft. long, 15 in. wide, and 0·15 of an inch thick, but could not get it. So with other alloys for which they had asked. The matter was one which affected not only the aluminium industry, but the engineering industry, with which the Institution was associated. The alloys that were wanted could not be supplied commercially. Regarding patriotism as a matter not only for war but for peace, users desired to avoid buying from foreign sources, but wished their supplies to be made here. They had been able to obtain under commercial conditions good results with British labour. With an alloy similar to the "Y" alloy, a test piece 1 in. in diameter, chilled cast, first annealed at 350 deg. C., and then heat-treated and "aged" in the usual way, gave a yield point of 16·68 tons per square inch, a maximum strength of 18·54 tons and an elongation of 2·4 per cent. Those figures were good, particularly in an alloy for piston use, and not likely to deteriorate greatly at temperatures of 250 deg. C. They would not, of course, compare with the 21 tons and 6½ per cent. elongation which had been mentioned. Stampings were made from a chill cast alloy, of which the maximum strength was 18·8 tons, the yield point 9·48 tons, and the elongation 4 per cent.; that yield point was significantly low. The best result obtained from a stamping gave a yield point of 9·15 tons, a maximum strength of 25 tons, an elongation of 22 per cent. and a reduction of area of 30 per cent. Those figures were commercial values.

In heat treatment there were strictly definite limits to the composition permissible, but these were not mentioned in the report; they would, nevertheless, be required in the commercial supply of alloys. To show how vital composition was, he instanced two lots of "Y" alloy sand castings purchased from different firms, and heat treated in the same bath at 520 deg. C. One behaved quite normally, but the other blistered considerably. The one yielded on analysis 4·1 per cent. copper, 1·96 per cent. nickel, 0·26 per cent. of silicon and 1·75 per cent. of magnesium. The alloy which blistered showed 3·6 per cent. of copper, 1·90 per cent. of nickel, 0·26 per cent. of silicon and 1·58 per cent. of magnesium and 0·46 per cent. of calcium. If it were supposed that a motor car manufacturer wanted a couple of dozen back axles cast in "Y" alloy, he would be told by the manufacturer that he could not provide the heat treatment. He thought it the duty of the manufacturer to bear the burden of heat treatment and to turn out the material to specification; the motor car maker could not be expected to do it.

Professor C. Frewen Jenkin, C.B.E., stated that, during the war, he was responsible for advising the Air Ministry as to the alloys to be used in aircraft, and at the outset it had been difficult to settle what to use. He had found that there was little accurate knowledge of any of the aluminium alloys with the partial exception of "Duralumin." One result of that was that he had been flooded with information on all sorts of alloys possessing marvellous properties. The Light Alloys Committee set to work. Investigations were begun; finally specifications for alloys were issued which could be recommended with fair confidence. Complaints, however, of all sorts of weaknesses were received, such as high temperature weakness, low temperature contractions, porosity, etc. These were all investigated by the Committee, assisted by the National Physical Laboratory. Nearly all the practical difficulties were solved, except one. Attention was then turned to the possibility of finding better alloys, and in that Dr. Rosenhain had been particularly successful, working at the new copper-nickel-magnesium alloy. Unfortunately this success was not attained in time to be of service to the Air Ministry during the war, but he understood that the alloy was being practically tried by users to-day. With regard to casting, he might perhaps say that a good deal of information would be found in his report on aircraft material, containing a summary of the work done in his Department during the war. The difficulty for which a satisfactory solution had not been found was the important one of corrosion. Failures due to this cause during the war were so serious as to

lead to the adoption of rules against the use of the alloys under certain circumstances. He did not think that the fundamental cause of corrosion had so far been discovered. As to the general use of the alloys in engineering, he had met with a great amount of trouble in their use in the aircraft industry, but the impression on his mind was that the alloys were not ticklish, difficult and troublesome, but, on the contrary, had come out of the investigations extraordinarily well.

Mr. Harold Moore, O.B.E., thought readers of the report would be helped by the addition of a summary showing the composition of the various alloys so frequently mentioned. On page 131 of the full report the authors had stated that the longitudinal central defect leading to lamination in extruded rod and bars was due to the drawing down into the bar of defects originally existing in the ingot, or drawing down into the bar of portions of the skin, particularly from the back of the original ingot. He thought the second of those causes was far more usual than the first, and that it was the skin from the external cylindrical surface which gave most of the defects in the extruded rod. The question had been thoroughly gone into by Mr. Genders in a paper read at the recent meeting of the Institute of Metals.* What was of greater practical importance was that Mr. Genders had also described a method of avoiding the defect which promised to be very successful. He congratulated the authors on the most important contribution yet made to the solution of the puzzling phenomenon of age-hardening. The capacity of undergoing age-hardening was of great practical importance in the application of aluminium alloys. The author's explanation of age-hardening threw light on some experiments made at Woolwich some ten years ago. The occurrence of age-hardening was accidentally discovered in an aluminium alloy containing zinc, copper, magnesium, and a number of alloys were made for the study of the phenomenon of compositions given in the table annexed. These were quenched from 50 deg., 100 deg. C., and at steps of 50 deg. C. up to 500 deg. C..

Age-Hardening of Aluminium Alloys.

	Cu.	Zn.	Mg.	Si.	Brinell hardness number. Quenched from 450 deg. C.	Brinell hardness number. Aged 14 days.
D	Nil	Nil	0·14	0·17	22	22
E	Nil	Nil	0·45	0·17	24	24
O	Nil	Nil	5·80	0·17	63	62
L	0·9	Nil	0·24	0·17	33	37
B	1·0	9·6	Nil	0·17	41	44
18	1·0	15·8	0·04	0·12	65	74
M	3·5	Nil	0·49	0·17	50	83
H	Nil	11·3	0·18	0·17	37	88
J	Nil	11·0	1·05	0·17	58	120
K	Nil	9·3	6·00	0·17	95	133
C	1·0	10·1	0·15	0·17	42	91
21	1·0	10·8	0·20	0·15	49	96
24	1·0	11·5	0·22	0·15	53	103

The Brinell hardness was determined immediately after quenching and at 1 hour, 2 hours, and at further intervals after quenching up to 56 days. The alloys were divided into two groups. In the first group, shown in the upper part of the table, there was little age-hardening, while the alloys of the second group showed intense and rapid age-hardening. A notable point was the presence of 0·12 per cent. to 0·17 per cent. of silicon. Magnesium alone produced no age-hardening effect, and very little age-hardening occurred with 10 per cent. Zn, 1 per cent. Cu, and no magnesium. A similar alloy with more zinc and a trace of magnesium showed a small but distinct age-hardening. These results agreed well with the author's views of the cause of age-hardening. In none of the alloys did the proportion of Mg_2Si exceed 0·50 per cent. Magnesium up to 6 per cent. clearly did not affect the solid solubility of Mg_2Si in a way which would cause age-hardening; 3·5 per cent. of copper, 10 per cent. of zinc, 10 per cent. of zinc with 1 per cent. of copper, all induced age-hardening, with magnesium varying from 0·15 per cent. to 6 per cent. In one alloy the Mg_2Si was only 0·24 per cent. It would seem that the solid solubility of Mg_2Si in aluminium had been reduced much below 0·24 per cent. by the presence of 10 per cent. Zn and 1 per cent. Cu. 1 per cent. Cu alone had not produced that effect. One piece of experimental proof of the author's theory was still lacking, namely, the absence of age-hardening in alloys of aluminium and magnesium with zinc or copper, free from silicon. The authors might be interested to know that most of his alloys, when age-hardened, were softened again by long annealing (several days) at 150 deg. to 200 deg. C. and did not regain their hardness on ageing even after some months.

Mr. H. J. Maybrey remarked that the authors had made no mention of the extrusion of the "Y" alloy, and he would be glad of informatiom on the point. He had recently had occasion to carry out some experiments in this direction, and so far had been tolerably successful, obtaining a uniformly good product. In carrying out tensile tests, when extruding down from a 5 in. or 4 in. billet to half an inch, he got a tensile strength of 24 tons per square inch with a 15 per cent. elongation. Another point he wished to speak about was pin-holing in the casting of the "Y" alloy. On recasting he had found there was a tendency for the pin-holing to be decreased without, apparently, in any way altering the composition of the alloy, if the recasting were carried out with a certain amount of care. He had had an analysis made of a "Y" alloy which had been recast at least half a dozen times, and he had found it difficult to alter the composition.

Dr. H. S. Hele-Shaw, F.R.S., referred to the fact that, some 40 years ago, a paper had been read before the Southampton Meeting of the British Association at which Armstrong, Baker, Bramwell Siemens, and other prominent engineers of the day had been present. After W. H. Barlow had read his paper on aluminium, then almost a laboratory product, Bessemer spoke, stating that he had been working on the subject, and produced an alloy which, he observed, was destined to take a great part in industrial work in engineering if it could be improved, and would be most important in the future aircraft. Nobody had then even thought of aircraft, and the present uses of alloys in aircraft rendered the point of considerable interest. He was interested in aluminium alloys not from the structural point of view but for its properties, particularly in relation to friction and lubrication, and he was hopeful that much more would be learnt in this direction. These alloys could be made for many purposes and were suitable for the wearing surfaces of pistons, a small but important matter. He hoped that, with the aid of microphotographs, exact knowledge of the changes which took place in them would be acquired, particularly if they were going to have an influence on working parts from a frictional point of view.

Dr. D. Hanson was the first of the joint authors to reply to the discussion. It had been suggested that as the alloys grew older they would become worse—that they would grow harder; some as a matter of fact would get softer, the question being one of the temperature at which they were aged. Age-hardening was in certain respects analogous to the hardening of steel, particularly certain special steels, but it was not identical. It was known that special steels, such as those containing nickel and chromium could be quenched in water, and after treatment were relatively soft. If stored at room temperature they remained soft; if reheated slowly to 200 deg. C. or 300 deg. C.—in some cases the heating was higher, according to composition—they became hard. The alloys under discussion were similar in that respect. After quenching from a temperature at which the compound Mg_2Si was dissolved—immediately after—the alloys were soft. At room temperature they hardened. When tempered at a higher temperature they first of all hardened and afterwards softened, just as steel could be let down by over tempering.

There was a difference, however. In steels, in addition to the change in solubility, there was a large volume change. Probably Sir George Goodwin had in mind what happened in the case of complicated steel shapes when these were quenched; they warped as a result almost entirely of the volume change accompanying the allotropic transformation. That state of affairs did not exist in the case of the alloys. It was mentioned in the report that gradual changes took place over a number of years, and the possibility that such changes might be accompanied by volume changes had been admitted. It was and could be said, however, quite definitely that the changes which accompanied ageing of the alloys were not attended by serious changes in volume. Further, provided the alloys were maintained at room temperature they were always accompanied by an increase rather than a decrease of strength. Referring to Professor Carpenter's argument, the material the authors were dealing with had, so far as they knew, internal stresses of a much smaller order than he had had, and there was no reason to suppose that any re-distribution that might take place would give the increase in hardening which had been noticed.

Mr. Moore's data supported the work which the authors had done upon alloys containing zinc, and further the conclusion that the addition of zinc did produce age-hardening properties, as did also percentages of magnesium silicide. They did not claim that magnesium silicide was the only substance that could produce the age-hardening effect in aluminium alloys; indeed, they wished to state definitely the probability that this effect could be found in a large number of alloys if the correct constituents were obtained.

Mr. Sydney L. Archbutt, F.I.C., said that the majority of the alloys described were essentially new alloys—the alloys A, E, and Y—and until the last few years there had not been any plant in the country properly equipped for rolling them. The users, therefore, had hardly had a chance, as Mr. Hoblyn had said. The plant for working aluminium was unsuited for working the harder and tougher alloys. Alloy A, for instance, was essentially a hot-rolling proposition, heavy pinches and rapid reduction being necessary in order to avoid cold work and other undesirable treatment. During the war a fine plant had been put down at the airship works of Messrs. Short Brothers, of Bedford, specially designed for the manufacture of these harder alloys which were satisfactorily produced on a commercial basis, and of excellent quality. Sheets of all three alloys, 0·05 in. thick and 12 in. wide, and 0·18 in. thick and 6 in. wide, was produced in 20 ft. lengths. In thicker gauges "Y" alloy plate, ½ in. thick and 18 in. wide, were produced in 12 ft. lengths. After the war this plant was taken over by the Admiralty and finally by the Air Ministry; it was now idle.

During the present year connecting rods and piston rings, the latter 12 in. in diameter, had been produced in wrought "Y" alloy and put into use in internal combustion engines, with advantageous results. As to castings, hundreds of tons of the alloy containing 3 per cent. of copper and 15 per cent. of zinc, were used during the war for aircraft and automobile construction, for general casting purposes, for crank cases, gear cases, brackets, &c., For pistons and cylinders the 12 per cent. copper alloy was largely used. More recently the advantages of "Y" alloy had been largely recognised, and satisfactory pistons and other castings had been made and used.

With regard to delicacy of treatment, careful control of temperature and heat treatment were essential, but did not in any way interfere with satisfactory production. The forging of these alloys had easily been accomplished at Bedford. In the final method of production of sheet, adapted for "A," "E" and "Y" alloys, slabs 9 in. by 18 in. by 1·5 in. (thick) were reduced by forging 30 per cent. in thickness, in two heats, without difficulty before rolling. Some very successful forging of large cast ingots had more recently been accomplished in "Y" alloy. He considered that the crux of the matter was a sound ingot and plenty of power. Experience in working the alloys, both at the laboratory and at Bedford, had shown that in respect to production of finished sheet free from defects, and reduction of scrap, preliminary forging was an undoubted advantage. In the case of the high tensile alloy "E" preliminary forging was probably essential for successful breaking down. The extrusion of the alloys was a more difficult operation. Alloy "A" extruded reasonably well, but a low temperature was necessary for alloys of

* See ENGINEERING, page 487 *ante*.

the "E" type, which necessitated very powerful presses. Extrusion of the "Y" alloy had not been attempted by the authors.

The effect of iron on aluminium alloys and the intentional addition of this element to cast alloys in America had been mentioned. That question had been investigated at the National Physical Laboratory and elsewhere on behalf of the Advisory Committee for Aeronautics during the war. The conclusion was drawn that, as far as foundry practice was concerned, there appeared to be no advantage to be gained by the intentional introduction of iron into aluminium alloys. The addition of iron to low copper alloys did increase their strength at high temperatures, but induced difficulties in the foundry which had not been surmounted. The iron-aluminium compound separated in the form of long needle-shaped crystals, and formed a kind of scaffolding from which the still molten alloy drained away during further solidification, leading to drawing and unsoundness.

Information had been asked for regarding the coefficient of expansion. Figures bearing on this point were given in the table subjoined. The results

Composition.	Condition.	Coefficient of Expansion.	Temperature Range. Deg. C.
Zinc aluminium.			
5 per cent. Zn	13/16th in. drawn, with annealing	$\cdot 000022_7$	0°—18°
15 per cent. Zn	" "	$\cdot 000023_1$	"
20 per cent. Zn	½ in. hot rolled	$\cdot 000023_4$	"
Copper zinc aluminium.			
Copper, 3 per cent.	½ in. hot rolled	$\cdot 000023_4$	"
Y alloy.			
Copper, 4 per cent.	Chill cast bar*	$\cdot 000022_4$	0°—36°
Nickel, 2 per cent.	Chill heat treated	$\cdot 000022_2$	
Magnesium, 1·5 per cent.	Rolled heat treated, ½ in. diam.	$\cdot 000021_8$	

* 1·2 in. diam.

for zinc-aluminium, and copper-zinc-aluminium alloys in the worked condition, were taken from the Tenth Report. Measurements had recently been made for the authors of the "Y" alloy in the cast, cast heat-treated and rolled heat-treated conditions; in every case the results were practically identical and of the order of twice that of steel.

The coefficient of expansion of pure aluminium was practically identical with that of its alloys. In common with the elastic modulus, the coefficient of expansion seemed to be a property fixed by the predominant atom or space lattice, and was little affected by the addition of other elements.

Dr. Walter Rosenhain, in conclusion, thought, with regard to Mr. Weeks' remarks at the previous meeting, the authors could hardly have paid "Duralumin" a higher compliment than that of using it as a standard of comparison. It was certainly a remarkable alloy, and he hoped that nothing said in the Report would in any way suggest that they were endeavouring to abrogate either the merits of the material, or those of the people who had made the alloy commercially available. He thought that Mr. Weeks had gone too far when he suggested that the comparison in the compression test was hardly a fair one. As a matter of fact, the "Duralumin" used was the standard heat-treated "Duralumin," and the authors' alloys were standard heat-treated wrought material, so the comparison was fair and proper. On the question of aluminium piston rods and their function, it was interesting to find that the several speakers had strenuously contradicted each other. Each, no doubt, was right from his own point of view. In such a thing as a submarine Diesel engine saving of weight was important. All he would say was that the saving might safely be carried a good deal further than it had been, not by using a lighter alloy, but by using rather less of it. With regard to scantlings, connecting rods of "Y" alloy had actually been made and were in use in certain high-speed engines, with precisely the scantlings of the steel connecting rods they had replaced. The supposition that the use of the alloys implied larger scantlings was not entirely justified.

With regard to ageing and permanence, he felt that Sir George Goodwin's remarks were based on a slight misconception. The authors, to begin with, had dealt with a whole series of castings and had found, in the course of something like ten years no measurable change of shape. The fear that a gradual distortion during use would interfere with their service was quite unfounded. The fear of distortion was a bogey and nothing more. The analogy between annealing and quenching in steel and other materials should not be pushed too far. Professor Jenkin had been a little more dramatic than accurate in stating that there was no accurate knowledge about aluminium alloys at the beginning of the war. Two or three reports, in which he (Dr. Rosenhain) had participated, previous to that presented at the meeting, suggested that there was some knowledge of the subject at the period named, although not, it might be, widespread.

Corrosion was a vital question. He could not help thinking that the fear was mistaken. There had been certain cases in which failure had occurred, these cases being ascribed—he held himself partly responsible—to the action of unsuitable protective coatings, containing, he believed, lead oxide. He might say, however, that lead oxide paints had, under careful experimental conditions, failed to reproduce the corrosive effects referred to. At the same time it was wise to refrain from the use of anything containing lead or other reducible oxides in the painting of aluminium castings. Apart from that, much work had been done towards producing oleo-resin varnishes, such as were used for rigid airships, while other varnishes were being experimented upon with highly satisfactory results. There were many engineering uses for light alloys into which fear of corrosion need not enter. "L 5" had been used in crankcases of aeroplane engines for some little time, and he had not heard of one that had failed. Other possible uses were in the underframes of motor cars, and in railway carriage underframes, without fear of corrosion, even of the most corrodible alloys, if reasonable measures for protection were taken. With regard to the "711" alloy, 7 copper, 1 zinc and 1 tin, this material certainly provided pretty castings, and they could be turned out in large numbers. The value of a casting did not, however, reside in its appearance, and that particular alloy had undesirable properties; its power of resisting shock at elevated temperatures was very low, and this defect was due to the presence of tin.

At the previous meeting mention had been made of "Electron." "Electron" was not essentially an aluminium alloy, but was a light alloy of a very interesting kind, of which an account had been given by Mr. Beckinsale of Woolwich, at the last meeting of the Institute of Metals.* The best of the alloys covered by the present report showed a specific tenacity of 360. "Y" and "Duralumin" attained to 268 and "A" to 262 specific tenacity, while for "Electron" it ranged from 250 to 284. Although, therefore, "Electron" compared with the latter alloys, it did not compare with the best. From the point of view of durability, an alloy containing mainly magnesium could not compare with even the most corrodible of the aluminium alloys. In factories where magnesium alloys were machined, extreme precautions had to be taken against fire. In this connection he might say that the Laboratory contemplated publishing shortly the results of an extensive series of researches on high magnesium alloys undertaken during the war. With regard to the alloys with silicon, he believed that they were being made in America, but the figures available with regard to them were so low as to make it difficult to understand their use. "As cast," they had rather more ductility than the copper alloys, were rather more ductile than "Y," but this was coupled with comparatively low strength.

Turning to the matter of engineering uses of these alloys, the text to Mr. Hoblyn's preaching was that we should get them made, and that certainly was the thing most to be desired. The alloys had been successfully made in works by ordinary workmen under ordinary works control. The question was, *who* would make them? If enterprise in this country did not succeed in putting them on the market they would be exploited elsewhere. He could only hope that that would not be so. The alloys had been dealt with, both at the laboratory and at Cardington, on such a scale that it was possible to indicate to any manufacturer wishing to take them up exactly how he should go about it. The alloys were not particularly difficult to manipulate, but supposing them to be so, he would ask where the more advanced branches of engineering would be to-day if it had been decided that the manufacture of special steel alloys should be given up because they required accurate heat treatment? He wished in conclusion to thank the staff of the Institution for the great assistance they had rendered in the preparation of the report for the press.

The President then announced that the Thomas Hawksley Lecture would be delivered to-day (Nov. 4) at 6 p.m., the subject being "Power Transmission by Oil," by Dr. H. S. Hele-Shaw, F.R.S., Vice-President. The next general meeting would be held on Friday, November 18, at 6 p.m., when a paper would be read on "The Machinery of Floating Docks," by E. H. Salmon, D.Sc.

* This paper is reprinted on page 641 of the present issue.

THE F.O.D. JACK FOR MOTOR CARS.

THE photographs reproduced below, show a new type of light screw jack devised particularly for the use of motorists. The usual rising screw column carries a loose head hinged to the ordinary head in such a manner that it may be swung into position when it is desired to increase the height of the jack. The handle which carries the bevel pinion is detachable, and can be pushed into its bearing in the jack casing, where it is held by a spring catch. The handle has a

link joint at about the centre of its length, so that the ends can be folded together for convenience in transportation, as shown in the illustration. Surrounding the handle is a sliding sleeve which renders the handle virtually rigid when pushed over the joint.

The jack is made of an aluminium alloy for the sake of lightness. It is built in three sizes, the smallest having a weight of 3 lb., a maximum height of 10¼ in., and a lifting capacity of 880 lb., while the largest weighs 5¼ lb., has a maximum height of 15¼ in., and will lift a ton. It is of Italian construction, and is sold under the name of the "F.O.D." jack, by Mr. H. A. Wanklyn, 17, Manchester-avenue, E.C. 1.

OIL SHALE.—Success has attended the initial trials of the Ironside oil shale reduction process, says *The South African Mining and Engineering Journal*. Waaihoek cannel coal, which averages 28 gallons to the ton, but which was reported on by Mr. McKillop, of the Scottish Oils, as being unsuitable for Scottish retorts owing to its tendency to clinker, was treated by the Ironside method. A yield of approximately 30 gallons to the ton was obtained and with no clinkering. A small test of Grenfell coal gave a yield of 25 gallons.

THE NORDBERG WINDING ENGINE.

(*Continued from page 566.*)

As already mentioned the ropes are flat, and of section 7¾ in. by ¾ in. They are wound on reels illustrated in Figs. 17 to 27, Plate XXXVIII, one hub being given in Fig. 20. On one side of the reel the casting is extended to provide a rim for the brake. To the side of this rim is bolted a clutch ring, which will be referred to later. Figs. 18 and 19 show the brake ring, and the manner in which this is bolted to the reel, a detail being given to a larger scale in Fig. 24. There are four rope grips, three of them being illustrated in Fig. 25, while a section through one grip is shown in Fig. 23.

Details of the brakes are shown in Figs. 28 to 31, and the accompanying small drawings, which will be easily located by their reference letters, &c. The view given in Fig. 34, Plate XXXVIII, shows very well the brake and its being also well shown in Fig. 32, on the same Plate. From the details of the construction given in Figs. 17 to 20, it will be seen that these reels have a bottom diameter of 75½ in., and an outside diameter of 18 ft. Each reel is made up of two side plates, each side plate again being parted on its diameter, as shown in Figs. 17 to 20. The reels run on babbited removable bushings, shown in Fig. 27, a detail of the servo-motor, and also incidentally the clutch which we shall deal with presently. The principle of the brake may be followed by reference to Fig. 33, Plate XXXVIII, which, though actually illustrating a smaller brake, shows one similar in all essentials to the Homestake installation, as regards the suspension of the brake shoes. From this it will be seen that the brake shoes are suspended on anchor bars C, D (Fig. 33), the point of suspension being in the middle of the brake shoe. There is a set of links and levers at each end of the brake shoe coupled to the operating lever placed on one of the shoes opposite to the point of suspension. This lever is attached to the piston of the servo-motor and also to a weight which sets the brake. The servo-motor is single-acting, and only serves to lift the weight and release the brake. It can be seen that by this arrangement the brake will act under all conditions and that the failure of the servo-motor or any of the connections between it and the brake would not prevent the brake from taking hold. A brake of this type requires no auxiliary hand-operating gear.

On the end of one of the shoes is a bracket connected by a rod A B, to the bedplate of the brake. This rod A B is of the same length as C D, so that the configuration A B C D is a parallelogram, the purpose of which is to prevent the brake shoes from tipping when they are released. The brake therefore acts like a parallel vice with even clearance all round. It is evident that a brake of this nature can be worked with a minimum clearance or with a maximum of leverage, so that it is well adapted to absorb a torque of great magnitude. The shoes, shown in Figs. 28 to 30, &c., are those used on the Homestake hoist. In order to obtain sufficient strength in these shoes they are trussed as is best shown in Figs. 29 and 30. The guide rod brackets B, and the fulcrum brackets D, are shown in Fig. 31.

DETAILS OF NORDBERG AXIAL PLATE CLUTCH AS BUILT IN SIZES OF 11 FEET AND LARGER.

Fig. 36.

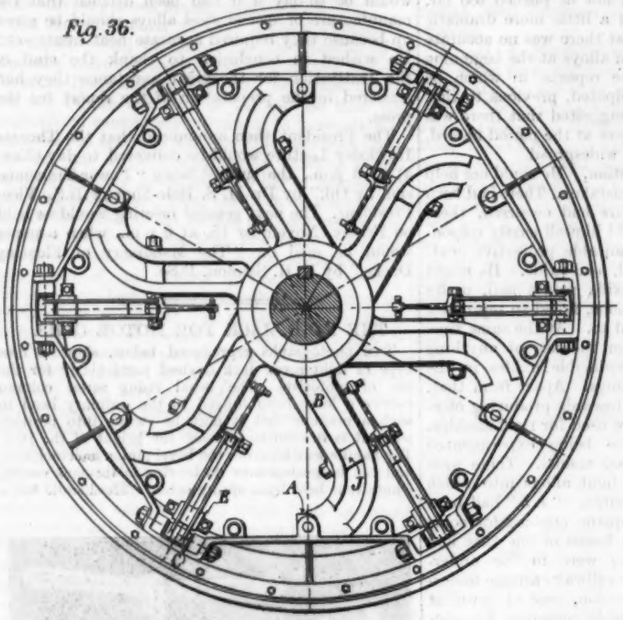


Fig. 37.

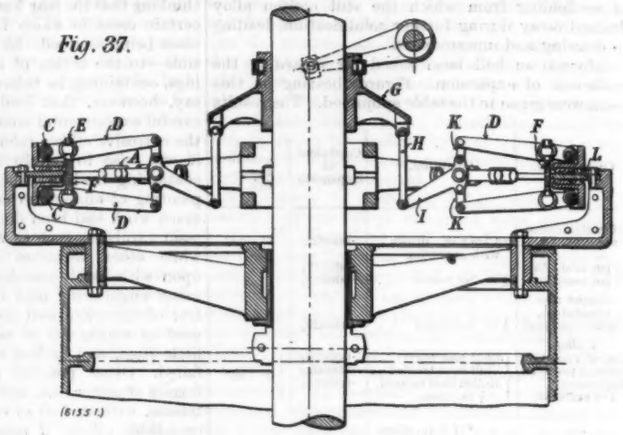


Fig. 38.

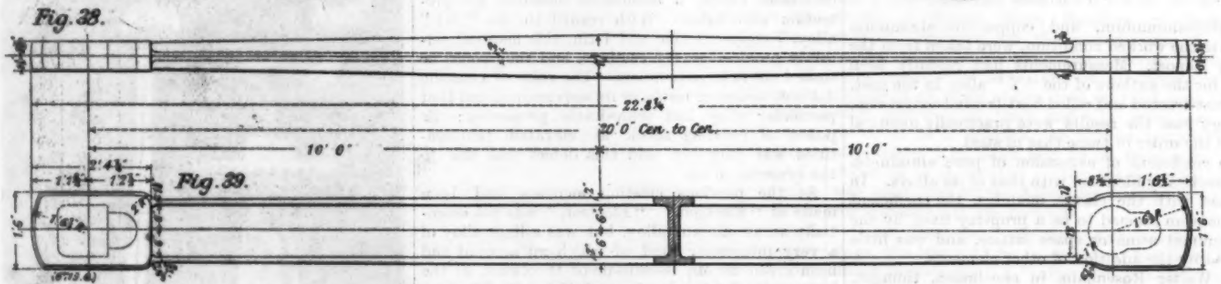
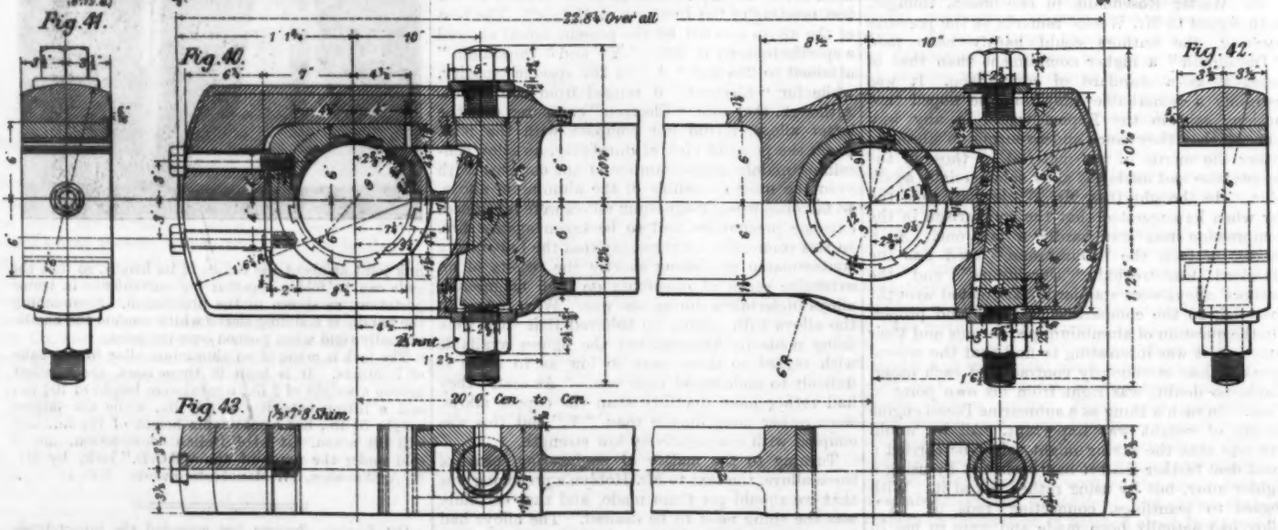


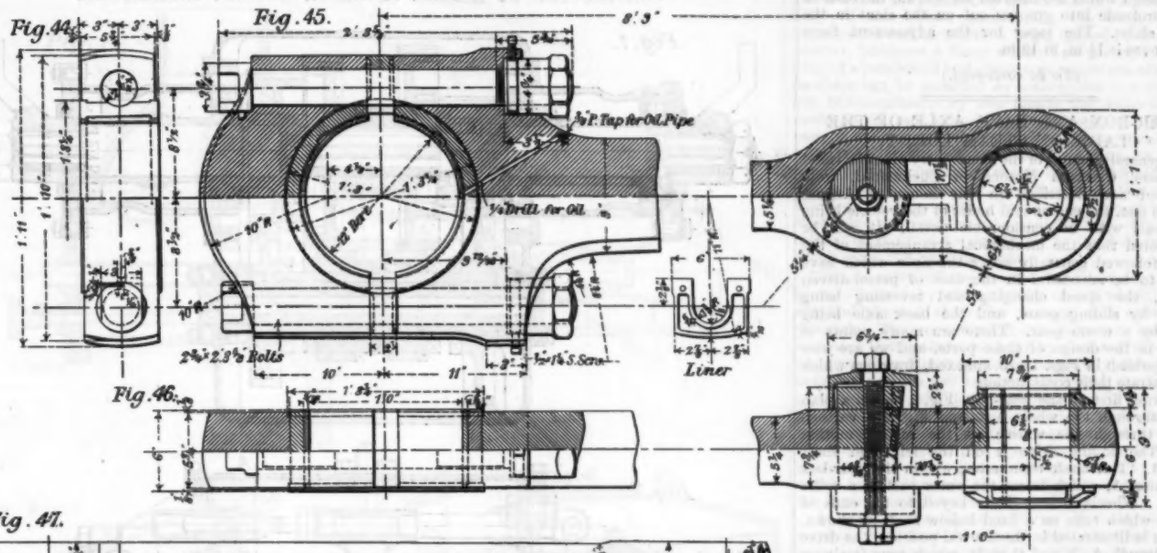
Fig. 39.

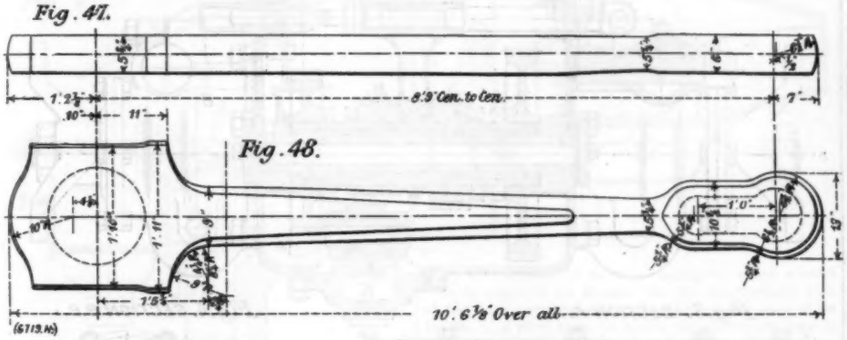
Fig. 41.

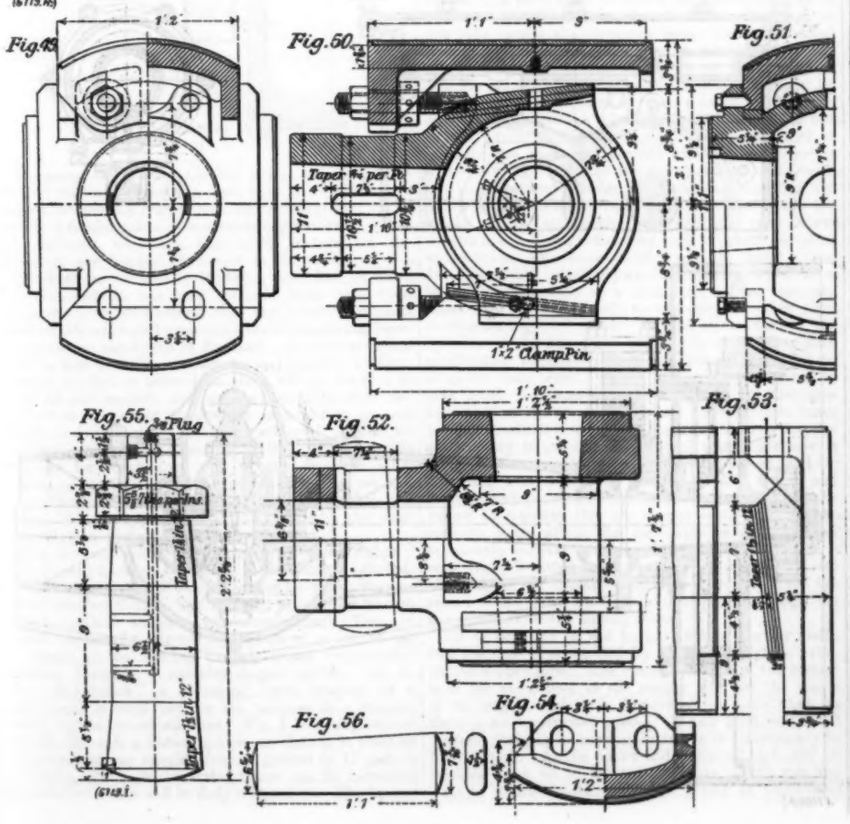


DETAILS OF COMPOUND WINDING ENGINE.

CONSTRUCTED BY THE NORDBERG MANUFACTURING COMPANY, MILWAUKEE, WIS., U.S.A.







The form of clutch used is illustrated in Fig. 35, Plate XXXVIII, and Figs. 36 and 37, page 628, though these do not illustrate the clutch actually used on the Homestake engine. The principle of the clutch will be clear from Figs. 36 and 37. The view, Fig. 34, Plate XXXVIII, shows the clutch on the engine we are describing. It will be seen that the clutch is of the axial type, the gripping elements consisting of two rings lined with basswood, each ring being made up of six segments bolted together as shown in Fig. 36. These segments are connected by the six pins A to the end of the arms of the driver B of cast steel, which is keyed solid to the shaft. At points C on the clamp rings are pivoted the clamping levers D. These levers are connected together at the point E by means of two long bolts F. The clutches are operated through the sliding piece G, links H, and bell cranks I, pivoted on pins J, fastened to the arms of the clutch driver B. By means of the short links K the motion of the lever I is transmitted to levers D, which, with E as a fulcrum, move the clutch rings in position to grip the plate L which is bolted to the reel. By means of the screws F the gripping power of the clutch can be adjusted. These clutches are very safe, as the holding power is not lost by the failure of any single part in the operating mechanism. It may be mentioned that at the ends of the pins A are rubber buffers which can be seen at M in Fig. 35. When the clutch is released and the driving discs spread apart, the buffers M are compressed, which takes out all the lost motion in the clutch so that it does not rattle when released.

Details of the side or coupling rods coupling the two cranks together, are shown in Figs. 38 to 43, page 628. These rods have centres 20 ft. apart and are of I section. The ends are solid, without strap or caps; the brasses are arranged with adjustment controlled by vertical bolts and nuts, the central portion of the bolt forming a wedge. One brass (at the right-hand end, Figs. 39 and 40) is fitted into a circular opening with a parallel extension on one side for the adjustable side piece. The other end has a rectangular opening for the brass with a small extension to one side for the adjustable piece. The square brass is fitted behind with a packing piece, and is drawn hard up against this by bolts seen in Figs. 40 and 43. This is a permanent adjustment for the final setting of the engine.

The connecting rod details shown in Figs. 44 to 48, are practically self-explanatory. These rods have 8-ft. 9-in. centres with big ends of the marine type and solid small ends fitted with adjustable brasses. The crank pins are 12 in. in diameter by 6 in. The bolts are 2¾ in. diam. Between the rod and cap are two fitting pieces shown in a small detail between Figs. 45 and 46. The small end is for a gudgeon pin 6½ in. diam. by 9 in. long. The brasses have wedge adjustment, which is controlled by a cross bolt and wedge working inside caps clearly seen in Fig. 46. The crosshead works in circular guides bored to a diameter of 25 in. Details of the crosshead are given in Figs. 49 to 56, Fig. 55 showing the gudgeon pin and Fig. 56 the cotter. The crosshead is fitted with two adjustable slippers, separate views of the latter appearing in Figs. 53 and 54. Four studs are screwed into the body

of the crossheads, and distance and lock nuts working on these keep the slippers up to the proper adjustment. The slippers slide on slanting faces between two flanges, one of which is shown in section in Fig. 51, and through which are inserted set screws, the ends of which protrude into grooves cut on the slant in the slipper slides. The taper for the adjustment faces and grooves is 1¼ in. in 12 in.

(To be continued.)

GEAR-BOX AND BACK AXLE OF THE CLARKSON STEAM LORRY.

THE general features of the steam lorry manufactured by Messrs. Clarkson Motors, of Chelmsford, were illustrated and described in our issues of August 9 and 16 last, the engine and boiler of the vehicle being then dealt with in considerable detail. It will be remembered that the mechanical arrangement of the chassis followed generally along the lines which have proved to be successful in the case of petrol-driven vehicles, the speed changing and reversing being effected by sliding gears, and the back axle being driven by a worm gear. There are many points of interest in the design of these parts, and we are now able to publish in Figs. 1 to 5, annexed, drawings which will illustrate their construction.

Referring first to the gear-box, Fig. 1 shows a plan section through the whole box, and Fig. 2 a vertical section through the wheels on the second motion shaft. The engine drive is on the left-hand shaft in Fig. 1. This shaft terminates, within the gear-box in a pinion A, which forms the outer part of a roller bearing. Wheels B and C are keyed to the ends of a sleeve which runs on a fixed hollow shaft as shown. The gear is illustrated in the neutral position, the drive being through A, B and C to D, which runs freely on the shaft. The wheels E and F have a set of internal teeth, by means of which they can be locked respectively to wheels A and D. They both ride on a spline shaft which they of course drive, and although made separately for mechanical reasons, they act as a unit, being moved together by the forks which embrace their bosses. If they are moved to the left, E becomes locked with A, and a "through" drive is obtained. If wheel G is moved to the left it engages with B by means of a dog clutch and the drive is through A, B, G and E. If wheel F is moved to the right it is locked to wheel D and the drive is then through A, B, C, D and F. Wheel H gears with another wheel K, not shown in this figure, and when it is moved to the right so as to lock itself with D, the drive is in the reverse direction and takes place through A, B, C, H, K, F. It will thus be seen that the gear-box provides three forward speeds, the fastest of which is a direct drive, and one reverse speed. Normally, of course, the direct drive alone is employed, the slower speeds being only necessary for starting or up-hill work, and even then to a much less extent than in the case of a petrol lorry on account of the greater flexibility of the steam engine. The ratio of the respective gears is 1 : 2 : 4 with a ratio of 3·6 for the reverse speed.

Fig. 2 shows the arrangement of one of the gear-shifting levers method of lubricating the back shaft and the gear wheels upon it. The wheel C carries up oil which it deposits in a recess communicating with the centre of the hollow spindle. A hole through the side of the latter allows the oil to get to the inside of the sleeve which runs upon it. Part of the oil then works out through the bearings of this sleeve, and the rest passes through holes in the sleeve to the interiors of the wheels G and H. Fig. 3 gives a cross-section through the gear-box and indicates the dogs which interlock the gear-shifting rods and positively prevent the gears being wrongly engaged. Fig. 4 shows a small worm gear which is used to drive a mileage recorder at the side of the chassis.

A section through the Clarkson rear axle is shown in Fig. 5. It will be noticed that the weight of the vehicle is carried by the axle itself and not by the axle-casing. The axle is made amply stiff enough to permit of this, and the design allows the bearings to be so far apart that the stresses upon them are much reduced and the wheels held more rigidly. The main bearings are of the roller type. The driving wheels may be removed without exposing the bearings to grit or dirt, and the halves of the axle may be readily withdrawn if necessary.

UNIVERSITY COLLEGE, LONDON.—University College has now issued the calendar for the session 1921–22, a volume of 600 pages, which gives a brief history of the college, the lists of committees and staff, of professors, deans, fellows, of prizes and scholarships, and detailed information on the numerous courses of study followed, lectures, &c. The Faculties represented are Arts, Science, Engineering, Laws and Medical Sciences; there are, besides, schools of Architecture and of Librarianship. The College also affords good facilities for post-graduate work and research.

GEAR BOX AND BACK AXLE OF STEAM LORRY.

CONSTRUCTED BY MESSRS. CLARKSON MOTORS, CHELMSFORD.

Fig. 1.

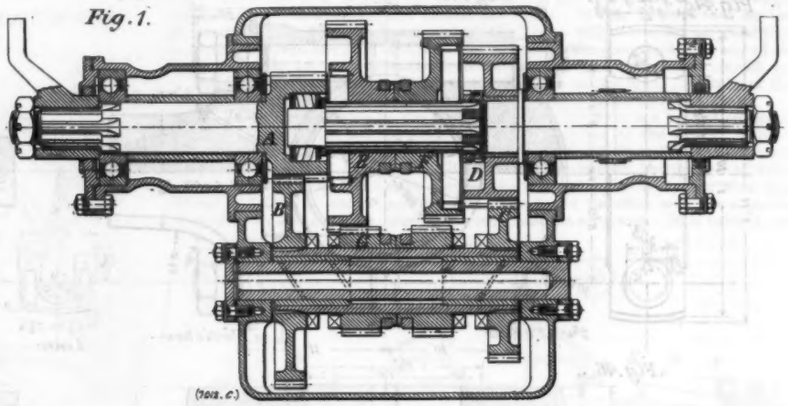


Fig. 2.

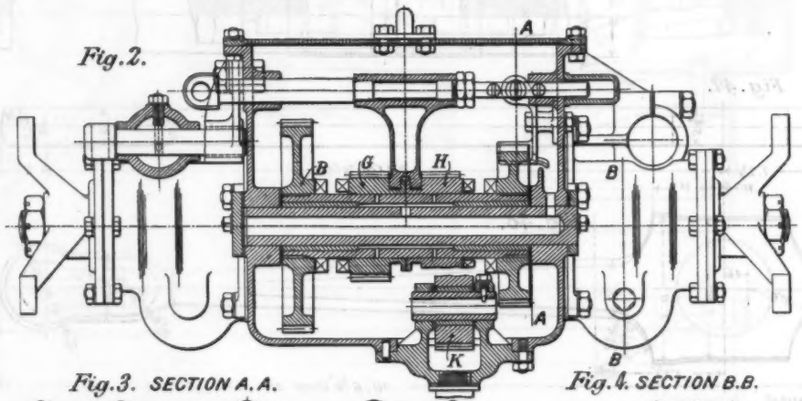


Fig. 3. SECTION A.A.

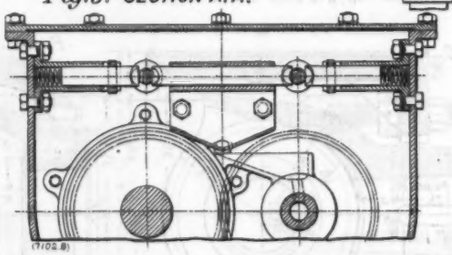
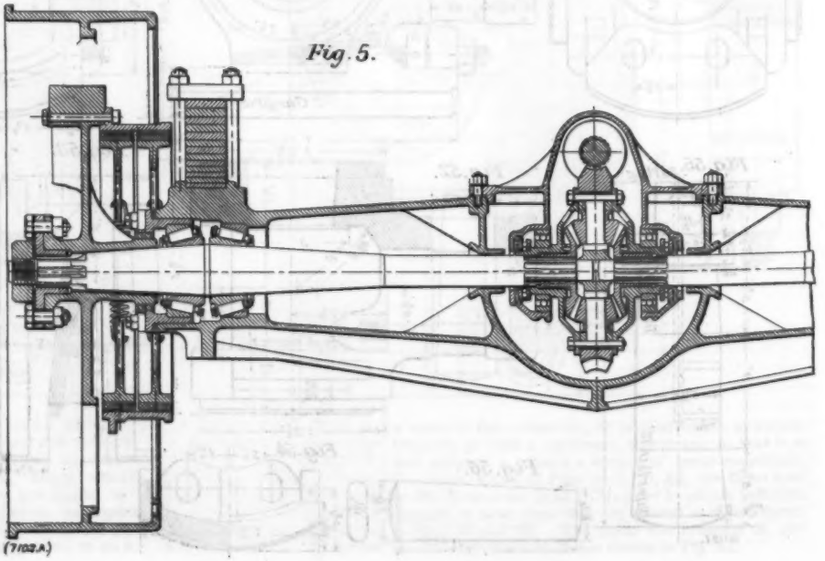


Fig. 4. SECTION B.B.

Fig. 5.



THE "ROTAMISOR" OIL-FUEL BURNER.

CONSTRUCTED BY MESSRS. COMBUSTIONS, LIMITED, KINGSTON-ON-THAMES.

Fig. 1.

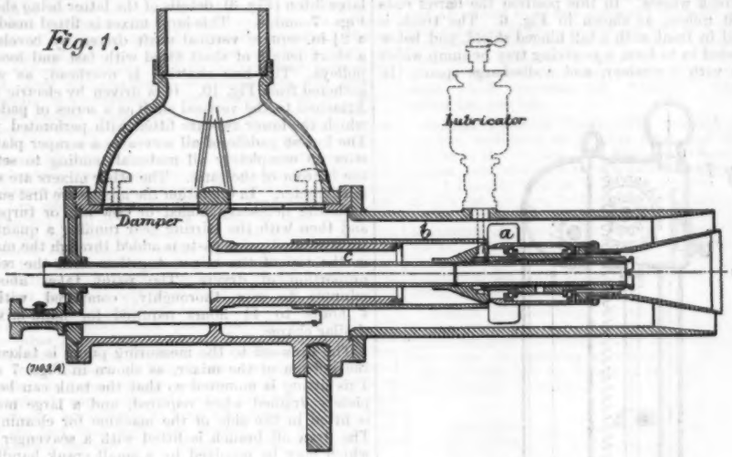


Fig. 2.

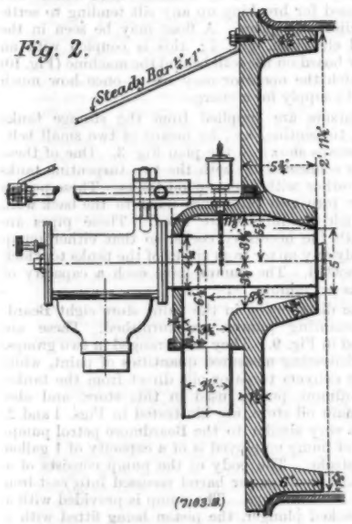
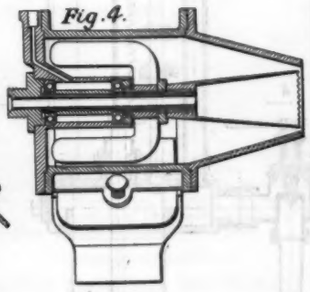


Fig. 3.

Fig. 4.



So many and varied are the types and designs of oil-fuel burners already in use, that a so-called new burner frequently turns out, on investigation, to be merely a modification of some existing pattern. There are, however, we think, such novel features in the design of the burner illustrated in the accompanying engravings as to justify its being described as new; but although it has only recently been put upon the market, we understand that the burner has been subjected to extended practical tests in a large engineering works in the North of England. It is unnecessary here to deal with the advantages and possible applications of oil fuel in general, as these will be familiar to most of our readers, but we may mention that the burner we are about to describe is either at present made, or is in process of being developed, to meet all requirements ranging from the heating of small muffle furnaces for tempering, &c., to the firing of large marine or stationary boilers, practically all types and sizes of industrial furnaces being included within this range. A wide application of the system is also contemplated in domestic and central heating.

The burner, which is known as the "Rotamisor" and is being handled by Messrs. Combustions, Limited, of High-street, Kingston-on-Thames, is the invention of Mr. Dudley Wright, and its most interesting feature is the method adopted for atomisation. This, of course, is usually effected by means of a jet of air or steam, or by forcing the oil under considerable pressure through a suitably-shaped orifice, but in the "Rotamisor" a diverging cone rotating at a high speed is employed for the purpose in a manner which will be described later. Fig. 1 is a longitudinal section through a burner which, as shown, is suitable for consumptions ranging from 4 gallons to 12 gallons per hour, although the latter figure can be increased by a device which will be duly referred to. The burner body is composed of an iron casting to which a steel tube is attached as shown. In the longitudinal axis of the body, and extending for the greater part of its length, is a steel tube to which the oil-supply pipe is connected at the left-hand end. The other end of this tube carries the divergent cone which is mounted on ball bearings so that it can be rotated at a high speed by means of a vane wheel lettered *a* in the figure. The air required for combustion, which is supplied by a fan at a static pressure of about 6 in. of water, is led into the body through a breeches piece seen on the left of the figure, two plate dampers being provided to regulate the amount delivered and also to divert it either through the outer annular passage *b* or through the inner annular passage *c*. In normal working, the damper controlling the inner passage is closed, and the whole of the air passing through the vane wheel rotates it at a speed sufficiently high to ensure complete atomisation, viz., from 3,000 r.p.m. to 9,000 r.p.m. It is, however, often required in practice to cut down the oil consumption to a minimum, as, for example, when it is desired merely to prevent a furnace from cooling during meal times. In these circumstances, the velocity of the air, when reduced in accordance with combustion requirements, would not be sufficient to keep the vane wheel running at the speed required to give good atomisation. The dampers are therefore adjusted so as to pass the air through the inner passage *c*, which is of smaller sectional area, so that the air velocity is greater. Moreover, a sliding sleeve is fitted on the outside of the inner air passage, and by adjusting this sleeve, by means of the screw and knurled nut provided, the area of the outlet can be varied to regulate the air supply while keeping the velocity with which the air impinges on the vanes reasonably constant. As will be seen from Fig. 1, a cone piece is fitted on the central oil pipe at the end of the inner air passage, and this serves to direct the air on to the vane wheel at about the same angle for any position of the sliding sleeve.

Oil is supplied to the burner from a gravity tank, and the flow is controlled by an ordinary globe valve on the supply pipe. The central oil pipe in the burner is of the same bore as the supply pipe for the whole of its length, and it is important to note that, as there is no constricted passage of any kind in the oil system, clogging is impossible and it is unnecessary to filter the oil. At the outlet end of the oil pipe, the oil trickles down on to the inner surface of the rotating cone to which it adheres by the action of centrifugal force, spreading into a thin film and travelling forward towards the outlet end owing to the divergent form of the cone. The delivery edge of the latter is formed with fine serrations which help to break up the oil film into an exceedingly fine spray, and this is carried forward into the furnace by the stream of air from the body of the burner surrounding the cone. The atomised oil and air mixture, being ignited in the usual manner, produces a flame which first diverges in the form of a paraboloid and afterwards converges, although its shape can be modified by making the cone more or less bell-mouthed; by this means the flame can be made to fill out a large space if required. In any case, it should be noticed that the flame converges at some considerable distance from the cone, so that a comparatively cool space is left immediately in front of the latter. This fact, together with the cooling effect of the air supply, keeps the cone at a very moderate temperature. As indicated in Fig. 1, a lubricator is fitted to supply oil to the ball bearings which carry the rotating parts.

The capacity of the burner, as illustrated, is, of course, limited by the quantity of air which can be supplied through the outer passage at a convenient pressure. The consumption can, however, easily be increased to 20 gallons per hour by means of the fitting illustrated in Fig. 2, which is especially suitable for boiler work. As will be seen, the fitting consists of a cast-iron plate provided with a flange to fit the furnace tube and having a central air hood through which the burner passes. The extra air required is delivered to this hood through a pipe which enters the hood tangentially, so as to give a rotary motion to the air, which leaves through the annular space surrounding the burner, as will be clear from the figure.

At present the burner is being made in two sizes smaller than that illustrated and described above, having capacities ranging from ½ gallon to 1½ gallons per hour and from 1 gallon to 5 gallons per hour. Another larger burner for consumptions up to 45 gallons per hour, is in process of development. We illustrate the smallest burner in Figs. 3 and 4, from which its design and construction will be clear with but little explanation. It will be noticed that, in this burner, the cone is rotated by a turbine wheel of the impulse type, and that the air regulation for all consumptions is effected by means of a single plate damper. This is possible because the variation in the air required is less than in the larger burner, and also because the arrangement is such that the air is delivered on to the turbine blades at a fairly uniform velocity, irrespective of the extent to which the damper is opened. In principle the burner is, of course, exactly similar to that previously described.

In addition to the advantages above referred to, it is claimed for these burners that the very fine atomisation produced results in an exceptionally good mixture, and consequently a "softer" heat, resembling that of a gas furnace, is obtained. We were also informed that no trouble has been experienced from the rotating parts sticking although some of the burners have been in service for upwards of two years. We have recently inspected a heating furnace suitable for forge work at the Kingston works of the company and fitted with the larger burner above described, although at the time of our visit the furnace was not actually heating bars. The oil in use was Shell-Mex fuel oil having a specific gravity of 0·95 and a calorific value of 18,700 B.Th.U. per pound, and air was supplied by an electrically-driven fan having a 3-in. outlet. The combustion appeared to be excellent, and the flame was readily adjusted so that it either filled the whole furnace, the internal dimensions of which were 8 ft. by 2 ft. 6 ins. by 1 ft. 6 ins., or extended only a few inches from the burner. We also saw the smaller burners working on muffle furnaces suitable for hardening or tempering operations. To demonstrate the atomising properties of the burner, a sheet of white paper was placed at a distance of about a foot in front of one of the smaller type, after it had been removed from the furnace. The oil spray collected on the paper was found to be composed of spots ranging from microscopic dimensions to about 0·04 in. in diameter, the average size being about 0·02 in. in diameter, or smaller. Owing to the subsequent spreading of the oil on the paper it is not possible to deduce the actual dimensions of the globules, but the diameters of the latter would evidently be much less than those of the marks on the paper. Another fact which may be mentioned is that the burner is not put out by the passage of a drop of water with the oil. The burner we saw was lighted up and operated with both air and oil supplied cold, but higher efficiency can, of course, be obtained by utilising the waste heat to preheat the air and oil supply when the burner is running.

In conclusion, it may be of interest to quote some data obtained in a comparative test of a coal-fired and an oil-fired furnace, the latter being fitted with the burner illustrated in Fig. 1. Both furnaces were used for heating billets measuring 6 in. by 4 in. by 4 in.,

for supplying drop-hammers, each furnace dealing with about 28 cwt. per day of 8 hours; the observations were made over a period of 50 hours, working on day shift only and covering one week's work. The temperature attained by both furnaces was about the same, viz., 1,250 deg. C., but the time required to heat the oil furnace to 960 deg. C. was 50 minutes, as compared with 80 minutes for the coal-fired furnace. The fuel consumption of the latter was 6,545 lb. for the 50 hours' work, giving a fuel cost of 23·31*d.* per hour with coal at 33*s.* 3*d.* a ton, while the corresponding figures for the oil furnace were: Total consumption, 2,287 lb., and fuel cost per hour 18·37*d.* with oil at 75*s.* per ton. Other operating costs for the oil furnace were: Labour 5·5*d.*, electric energy for operating fan 2·25*d.*, and handling fuel 0·04*d.*, while for the coal furnace the labour cost was 8·5*d.*, and the cost of handling fuel and ashes 2·3*d.* (all per hour). It thus appears that the total working costs for the coal-fired and oil-fired furnaces were 34·11*d.* and 26·16*d.* per hour, respectively, showing a saving of 7·95*d.* per hour in favour of the latter for the particular fuel prices mentioned. Both furnaces have been running for a period of fourteen months, and the cost of upkeep, we understand, has been about the same for each. The oil furnace, however, occupies less floor space than the coal furnace, since more space is required for combustion in the latter, and it could also have given a greater output had the hammers been able to deal with it. From the points of view of cleanliness and convenience in working the oil furnace would, of course, have considerable advantages.

SHIPYARD BULK STORAGE OIL AND PAINT PLANT.

Having regard to the present high costs of lubricating and paint oils, a good deal more attention is nowadays paid to efficient systems of storing and handling these than was formerly considered necessary, and the resultant plants are frequently well designed, and great improvements on the older methods. As an interesting example of a modern plant of this character we illustrate in Figs. 1 to 10 on this page and on page 634, an installation recently put down at the new yard at Haverton Hill-on-Tees, of the Furness Shipbuilding Company. This plant was designed and made by the Dowson and Mason Gas Plant Company, Limited, of 3, Manchester-street, London, W. 1, who are the manufacturers of the Beardmore storage tanks and pumps used.

The plant has been designed with steel storage tanks, and automatic measuring pumps for the distribution of the oils, the lay-out being such as to reduce the cost, and increase the ease of handling. In the particular case under notice the plant comprises both oil storage and paint mixing, both being supplied with sets of automatic measuring pumps. The pumps are illustrated in Figs. 1 and 2, and are shown as installed in Fig. 9, page 634. The two portions of the plant are separated by partition walls as may be seen from our figures. Referring first to Figs. 3 to 4, these give plan and cross-section of the general installation. The photographs reproduced in Figs. 9 and 10 are interior views of the paint-mixing and distribution room. This room will be seen in the plan Fig. 3, to be partitioned off, as just stated, from the main oil-storage building, and to occupy the right-hand lower portion of our illustration. The floor level of the main building is at platform level, as regards the surrounding ground, and outside is a platform with a railway siding alongside. Barrels of oil can be rolled direct from the trucks in which they arrive straight on to the platform, and do not have to be lifted by crane.

The oil storage tanks are all below the floor, as is clear from Fig. 3, and from the section shown in Fig. 4. There are altogether 13 storage tanks, of which nine are allotted to lubricating oils, &c., and the remainder respectively to raw and boiled linseed oils and to natural turpentine or mineral substitutes. All oil storage tanks, with one exception, which holds 800 gallons and is reserved for fuel oil, are of 200 gallons capacity, while the tanks for the paint section are capable of containing 250 gallons. The tanks are all of mild steel and welded throughout. They are cylindrical, placed horizontally on brick settings, and each is provided with an 18-in. by 12-in. manhole, to the cover of which are fixed suction and gauging connections. The tanks are all filled from the raised floor level of the outside platform through fill boxes and pipes shown in Fig. 4, and in detail in Fig. 5. The filling pipes are 3 in. in diameter and each is fixed to a cast-iron fill-box grouted into the floor, closed when not being used, by a screw cap, flush with the floor. For gauging, a short 1½-in. vertical pipe is used, terminating under a hinged manhole cover in the floor, as shown in Figs. 3 and 4. A calibrated gauge rod is fitted to each tank and stands in this pipe. On this rod the contents are marked in gallons for direct reading on lifting the rod out of the pipe.

On being unloaded from a railway wagon to the platform the barrels are rolled on to barrel trucks of the type shown in Fig. 6. This is much like an ordinary hand truck, but the handles serve the purpose of a ramp up which the barrel is rolled to a position close to the truck wheels. In this position the barrel rests on small rollers, as shown in Fig. 6. The truck is furnished in front with a tall hinged shield, and below it is sheeted in to form a receiving tray or sump which is fitted with a strainer, and a discharge spout. In

Fig. 1.

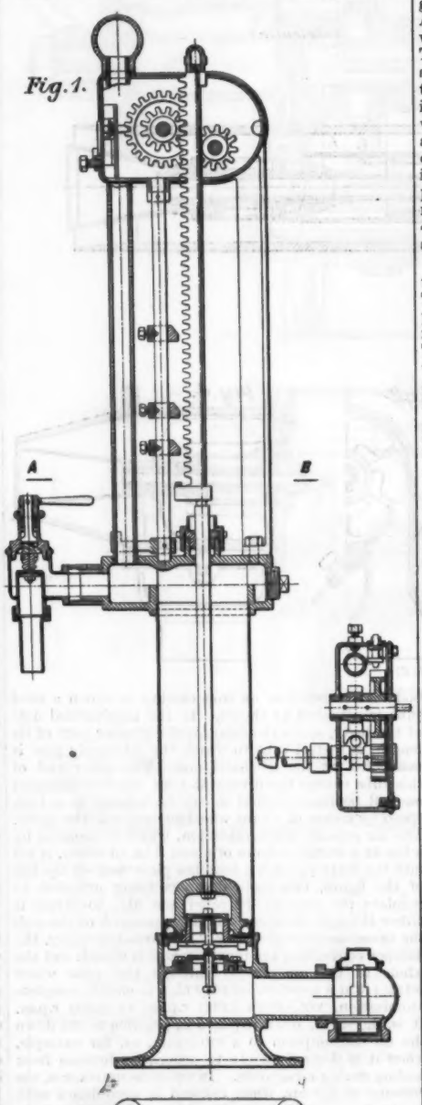


Fig. 2.
SECTION A.B.

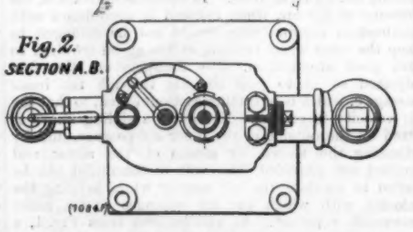


Fig. 6 the truck is shown in position over a filler box, and when placed in this position over the proper tank the bung is removed from the barrel, which is then turned over on the rollers towards the front shield and finally brought into the upside-down position over the receiving tray. It may then be left to drain unattended, thus eliminating a good deal of the labour besides ensuring more effective emptying than is possible with pumping.

The pumps for the distribution of the oils and paints are similar, and we shall therefore describe them later. We may draw attention here to the fact that each pump has a 2-in. suction pipe, and the nine pumps for the oil storage tanks are all brought together in a row, spaced 2 ft. apart and forming a very neat group. The paint plant is power driven with the mixers placed below the floor, the level of which is arranged flush with their tops, as will be seen in Fig. 10. In this installation there are three 1-ton mixers, and one large 3-ton (Fig. 3), details of the latter being shown in Figs. 7 and 8. This large mixer is fitted inside with a 2¼-in. square vertical shaft driven by bevels from a short length of shaft fitted with fast and loose belt pulleys. The line shafting is overhead, as will be gathered from Fig. 10. It is driven by electric motor. Attached to the vertical shaft is a series of paddles of which the lower two are fitted with perforated plates. The lowest paddle of all serves as a scraper plate and stirs up completely all material tending to settle to the bottom of the tank. The other mixers are similar in character. In operation the mixers are first supplied with the necessary boiled or raw oil, or turpentine, and then with the stirring gear running a quantity of concentrated paint paste is added through the manhole in the top of the mixer, together with the required proportion of dryers. The paint takes about 30 minutes to mix thoroughly, compared with the 4 hours to 4½ hours required for hand-mixing a similar charge.

The draw-off to the measuring pump is taken from the bottom of the mixer, as shown in Figs. 7 and 8. This fitting is mounted so that the tank can be completely drained when required, and a large manhole is fitted in the side of the machine for cleaning out. The draw-off branch is fitted with a scavenger blade which may be revolved by a small crank handle and can be used for breaking up any silt tending to settle in this discharge piece. A float may be seen in the sectional elevation, Fig. 7; this is coupled with an indicator board on the wall behind the machine (Fig. 10) from which the operator may see at once how much oil, &c., to supply for a charge.

The mixers are supplied from the storage tanks with oil, turpentine, &c., by means of two small belt-driven pumps shown in the plan Fig. 3. One of these pumps is connected up with the two turpentine tanks and the other with the two oil tanks. These pumps discharge into two pipe lines fixed to the back wall, from which the mixers are filled. These pipes are fitted with the necessary cocks, so that either pump can supply any mixer from either of the tanks to which it is connected. The pumps have each a capacity of 30 gallons per minute.

For the distribution in the paint store eight Beardmore measuring pumps are furnished. These are illustrated in Fig. 9. They are arranged in two groups, one set delivering measured quantities of paint, while the other delivers turps or oils direct from the tanks. The Beardmore pumps used in this store, and also for the main oil store, are illustrated in Figs. 1 and 2. They are very similar to the Beardmore petrol pump. The size of pump employed is of a capacity of 1 gallon per full stroke. The body of the pump consists of a light solid-drawn copper barrel recessed into cast-iron base and head castings. The pump is provided with a leather-packed plunger, the piston being fitted with a central valve. To the top end of the piston rod is attached a rack which passes through a head casting in which is arranged a train of reduction gears from a pinion driven by a crank handle. The head contains a snap lock so that the pump can be locked when not in use. In the base of the pump is a foot valve, and an additional external retaining valve is fitted to prevent all possible leakage back to the pipe line. The discharge takes place through a quick action anti-drip valve on the pump front. The internal lip of this valve is arranged at such an elevation that the quantity of oil standing at the lip level is very small, and only very little therefore can possibly drip. In addition a valve is seated on this lip and can be closed down as soon as the measured quantity has been discharged.

The pump is arranged for measuring 1 gallon, or ½ gallon, 1 quart or 1 pint, by means of stops shown on a rod to be seen in Fig. 1, limiting the piston stroke. These stops radiate at different angles from the rod, which can be swung round by the small hand lever seen in the plan Fig. 2. This lever can be set to bring either one or other of the stops into action as required. Every quantity pumped is measured and recorded on an automatic counter fixed to the head of the pump and to be seen in the view Fig. 9. This records the totals, and in conjunction with the calibrated dip-rods by which the contents of the tanks may be ascertained, daily stock-taking presents no difficulties. The distribution of mixed paints by measuring pumps is, we believe, a practice adopted for the first time in this instance. The absence of the usual messy measuring cans with the usual drips and dirt, together with the general convenience of the installation we have described, are features the advantages of which are very appreciable indeed, while labour costs have been reduced to a minimum; a point, in these days, also of considerable advantage.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The general feeling is that Sheffield has done exceptionally well respecting the British Admiralty contracts. The manufacture of half the armour plate and some of the machinery and guns required for the four new battle-cruisers will find a lot of work for departments that have been idle or only partially employed for six to twelve months. Heavy tonnages of steel and tools will be needed to carry out the various contracts, and in that manner toolmakers and other non-armament establishments will benefit. Though of considerable advantage, however, these orders cannot compensate for the general quietude in home and foreign business. In some respects the outlook in the engineering section is brighter. Here and there substantial orders have been booked for textile machinery, steel-works plant, locomotives and electrical equipment, and some of the more fortunate departments are working at top pressure despite the fact that Sheffield's unemployed total still exceeds 30,000, or three times the average number registered in normal periods. But the general condition of order books is unsatisfactory. The fact that prices of raw and semi-finished materials are still in many cases on the down grade, notably with respect to billets and steel bars, does not greatly help the position, as potential buyers are unwilling to place forward contracts until quotations are stabilised. On the other hand, hope is drawn from the fact that the difference between Sheffield and Continental quotations for many classes of basic materials and semi-finished goods has been greatly reduced, and in a few cases completely wiped out, and further, that many Continental producers are refusing to book additional business owing to the fact that works are already overtaxed by commitments entered into. Work is badly needed in the special steel branches.

South Yorkshire Coal Trade.—The sustained demand made by manufacturers for lower contract prices is reflected in a further reduction of 2*s.* to 2*s.* 6*d.* in the case of Yorkshire and Derbyshire hards. Some of the local collieries have apparently got to the end of orders, and are carrying on at reduced pressure with the greatest difficulty. Inquiries on export account continue to increase, but prices are against the arrangement of big business. Trade in gas fuels has slowed down. Inland works are not taking anything like their former tonnage. Stocks are accumulating at sidings. An increase in coke production is reflected in the stronger tone which prevails in the market for smalls. House coal is rather more active, but depots could comfortably handle many more orders. Quotations :—Best branch handpicked, 40*s.* to 41*s.*; Barnsley best Silkstone, 40*s.* to 41*s.*; Derbyshire best brights, 35*s.* to 36*s.*; Derbyshire best house, 35*s.*; Derbyshire best large nuts, 30*s.* to 32*s.*; Derbyshire small nuts, 27*s.* to 29*s.*; Yorkshire hards, 29*s.* to 30*s.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; rough slacks, 17*s.* to 18*s.*; nutty slacks, 16*s.* to 17*s.*; smalls, 5*s.* to 10*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—As was expected Cleveland pig-iron prices have been further reduced, but the extent of this week's fall is considered insufficient to tempt customers into the market. Thus the lower rates have inspired little hope of early improvement in trade. Costs of production are still much too high to admit of profit to makers, and consequently there seems little likelihood of much expansion of output by the re-starting of idle plant. No. 1 and No. 3 G.M.B. are each down 10*s.*, lowering prices to 115*s.*, and 110*s.* respectively for home consumption, and 120*s.* and 115*s.* for shipment to foreign destinations. A drop of 14*s.* in No. 4 foundry brings the market rate of that commodity down to 105*s.*; and No. 4 forge and mottled are now each quoted 100*s.*—a fall of 5*s.*

Hematite.—There is very little doing in hematite, and with output a good deal in excess of requirements curtailment of production would cause no surprise.

Coke.—The situation as regards coke is unsatisfactory. Prices are easing, but they fall much too slowly to suit customers. Durham blast-furnace description can be bought at 30*s.*, delivered, but local users now consider that rather too high a figure.

Shipments of Iron and Steel.—The shipments of iron and steel from the port of Middlesbrough during October were the best recorded for twelve months past, the grand total reaching 53,818 tons as compared with 43,839 tons in September and 28,213 tons in August. Clearances of pig-iron for October amounted to 16,959 tons, of which 5,926 tons went to foreign ports and 11,033 tons coastwise. The chief customers were Italy with 2,250 tons, Belgium 1,642 tons, and Denmark 450 tons. Shipments of manufactured iron and steel totalled 36,859 tons; 32,487 tons went to foreign ports.

Manufactured Iron and Steel.—Transactions in finished iron and steel are still few and small, but inquiry for some descriptions is rather better.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Little fresh can yet be reported with regard to the steel trade of Scotland, but the advent of fresh orders in connection with the new Admiralty contracts has brightened the outlook considerably. In the case of black sheets there is also little business going through, but foreign inquiries point to the fact that these markets are very bare, and may have to secure fresh supplies in the near future. Prices over all are without change, but the recent reductions have not as yet been responsible for much in the way of new business.

Malleable Iron Trade.—Development of any kind in the bar iron trade of the West of Scotland is very slow, and all efforts to obtain sufficient work for a full week's running seem futile. Orders are still very scarce, largely because of the competition which obtains through Continental material being so cheap. The home producer will come into his own later on, but it is the present state which concerns all. "Crown" bars are still called 14*l.* per ton.

Scottish Pig-Iron Trade.—The demand for Scottish pig-iron continues to be very slow, and there are few buyers in the market. No change has been made in the output, but prices are a shade easier with makers quoting No. 1 foundry iron at 7*l.* 2*s.* 6*d.* per ton, and No. 3 at 6*l.* 17*s.* 6*d.* per ton, both loaded into wagons at makers' works. Hematite, for which there is a very poor outlet at present, is called 7*l.* 5*s.* per ton, delivered at the steel works. The Continental brands of pig-iron are being freely used to the detriment of the local producers on account of the lower prices being quoted. There is little doing in export.

Scottish Shipbuilding.—While the outlook for firms fortunate enough to have secured the orders for the new battle-cruisers has considerably improved, the prospects for other shipbuilding concerns are far from bright. The following are the totals of launches in October for the different districts :—

	Vessels.	Tons.
The Clyde	14	55,979
The Forth	1	1,823
The Tay	—	—
The Dee and Moray Firth ...	1	257
Total	16	58,059

The figures for the River Clyde are the third highest for this year, the previous best month being February, with 25 vessels of 82,431 tons, and March with 30 vessels of 56,410 tons. The total is also above the average October output and is the third highest during recent years, the figures for the corresponding month of 1913, the record year, were 25 vessels of 71,644 tons, and for 1911, they were 24 vessels of 58,186 tons. For the year to date there have been launched 195 vessels amounting to 405,995 tons, which total is nearly 154,000 tons less than for the same period of 1913, and rather over 111,000 tons less than the ten months of last year.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—At a meeting of the Welsh Coal Board yesterday the general wage rate for November was fixed at 28·95 per cent. above the 1915 standard, or 0·95 per cent. above the minimum. The new wage rate represents a reduction of about 4*s.* per day on the October rates and is 50 per cent. below the October percentage, and about 150 per cent. below the rates in operation before the three months' strike. For underground workmen the November rates average a minimum of about 9*s.* 2*d.* per day, compared with 7*s.* 9*d.* in June, 1914. Another important development during the week is the fact that the South Wales dock companies decided to reduce their rates on shipping and charges for handling coal, &c., by about 10 per cent. to 15 per cent. from November 1. The new rates are, however, more than 100 per cent. in excess of the pre-war charges. For instance, the charge for tipping and weighing coal in 1913 was 2½*d.* per ton, but the present cost is 1*s.* 1*d.* while the charge for bunkering foreign-going steamers, sailing without cargo, is 10*d.* compared with 4*d.* Though the reduction came as a welcome surprise traders consider that the railway companies have not made a big enough cut and the coalowners, exporters, importers and shipowners have formed a joint committee to go into the matter with a view to securing further reductions. On the coal market business remains as unsatisfactory as ever, notwithstanding that best Admiralty large coal is available at 27*s.* 6*d.*, Monmouthshire Black Vein large 26*s.*, Western Valley large 25*s.* 6*d.*, and Eastern Valley large 25*s.*, the lowest prices touched for at least three years. Small coals, however, maintain a steady tone owing to the scarcity of these descriptions as a result of numerous stoppages in the coalfield. In the majority of cases colliery salesmen refuse to sell small without large except at a premium of about 6*d.* to 1*s.* per ton. Best steam smalls realise 18*s.* 6*d.*, ordinaries 17*s.*, cargo sorts 16*s.*, and good dry smalls 15*s.* Coke, too, is much weaker owing to the fact that more batteries have been started and the output increased. A week or so ago it was impossible to secure foundry coke under 60*s.*, but sales are now taking place at 45*s.* f.o.b. for export, and at the same figure at ovens for inland.

Iron and Steel Trades.—The Welsh tin-plate makers have refused a request by the men that the sliding scale should be suspended in view of the fact that the last ascertainment of selling prices only entitled them to a bonus of 7½ per cent. Eventually the employers offered the men an additional 10 per cent. on the 7½ per cent. bonus in view of the cost of living, and though the men asked for 30 per cent., it is expected that they will accept the employers' offer. Works are operating at a loss, but the recent improvement shown in the trade has been maintained. Stock plates are in request, and merchants are reported to be buying for November-December-January delivery up to 21*s.* 6*d.* per box.

NOTICES OF MEETINGS.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS.—Monday, November 7, at 7 p.m., at the Y.M.C.A., Albion-street, Leeds, when Mr. A. E. Kyffin will read his paper on "Notes on Axleboxes and Axlebox Guides." The chair will be taken by Mr. A. C. Stamer.

THE SOCIETY OF ENGINEERS (INCORPORATED).—Monday, November 7, at 5.30 p.m., in the Apartments of the Geological Society, Burlington House, when a paper will be read on "Extraction Turbines," by Mr. C. H. Naylor, A.M.I.C.E., of the British Thomson-Houston Company, Limited, illustrated by lantern slides.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, November 7, at 7 p.m., at the Institution of Electrical Engineers. Discussion : "How Best to Speed-up Electrical Progress," to be opened by Mr. J. S. Highfield, President.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Monday, November 7, at 5 p.m., at Albemarle-street, Piccadilly, W. 1. A General Meeting of the members.

THE CLEVELAND INSTITUTE OF ENGINEERS.—Monday, November 7, at 6.30 p.m., in the Hall of the Cleveland Technical Institute, Corporation-road, Middlesbrough, when Mr. R. H. Archer Coulson will deliver his Presidential Address.

THE INSTITUTION OF ELECTRICAL ENGINEERS : SCOTTISH CENTRE.—Tuesday, November 8, at 7.30 p.m., in the Rooms, 207, Bath street, Glasgow ; the chairman, Mr. E. T. Goslin, will deliver his Inaugural Address. *Student's Section* : Friday, November 11, at 7·30 p.m. Room 149, Royal Technical College, Glasgow ; Mr. Alex. Lindsay, chairman, will deliver the Opening Address.

THE INSTITUTE OF METALS.—*Scottish Local Section* : Tuesday, November 8, at 7.30 p.m., in the Rooms of the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow ; Mr. John Stirling will open a discussion on "Problems Awaiting Solution." *Birmingham Local Section* : Tuesday, November 8, at 7.30 p.m., in the Chamber of Commerce, New-street ; a discussion on "Annealing." *London Local Section* : Thursday, November 10, at 8 p.m.; at the Royal School of Mines, South Kensington ; Professor C. H. Desch, D.Sc., Ph.D., will read a paper on "Plastic Flow in Metals."

THE INSTITUTE OF MARINE ENGINEERS.—Tuesday, November 8, at 6.30 p.m., "Liquid Fuel and its Application for Steam Generation," by Mr. J. H. Anderson, Member.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, November 8, at 5.30 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, W.C. 2. Paper on "The Elimination of Oil Field Losses," by Mr. A. Beeby Thompson, O.B.E., M.I.Mech.E., M. Inst.M.M., F.G.S.

THE ROYAL SOCIETY OF ARTS.—Wednesday, November 9, at 8 p.m. "The Work of the Industrial Fatigue Research Board and its Applications to Industry," by Mr. D. R. Wilson, M.A., Secretary of the Industrial Fatigue Research Board. Mr. William Graham, LL.B., M.P., Member of the Medical Research Council, will preside.

THE OPTICAL SOCIETY.—Thursday, November 10, at 7.30 p.m., at the Imperial College. The following papers will be presented : "The Path of Rays in Periscopes having an Inverting System comprising Two Separated Lenses," by Dr. Alexander Gleichen (communicated by Dr. James W. French) ; "The Interocular Distance," by Dr. James W. French ; "Note on the Thin Astigmatic Lens," by Mr. T. Chaundy, M.A.

THE ROYAL AERONAUTICAL SOCIETY : STUDENTS' SECTION.—Thursday, November 10, at 7 p.m., Students' Discussion Meeting in the Society's Library, when a paper will be read by Mr. W. L. Le Page, on "The Soaring Flight Problem." Mr. Handley Page, Fellow, will take the chair.

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, November 11, at 7.30 p.m., in the Lecture Theatre of the Literary and Philosophical Society, Newcastle-upon-Tyne. "The Working of a Modern Telephone System," by Mr. C. Whillis, M.I.E.E., Sectional Engineer to the Newcastle South Section of Post Office Northern Engineering District.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, November 11, at 8 p.m., at Caxton Hall. Question and general discussion evening.

TRIALS OF THE GERMAN ARMOUR PLATE : ERRATUM.—We regret that in our report of the trials of the German armour plates, published on page 610 of our issue of last week, we made the mistake of giving the thickness of the plates in "pounds per square inch" ; this ought to have been "pounds per square foot." The mistake originated in the official tabulated statement of the trials.

ELECTRICAL ACCUMULATORS.—With reference to a notice of a pamphlet giving information and instructions for working Edison accumulators for electrically-driven vehicles which appears on page 556 of our issue of October 14 last, under the heading "Catalogues," Messrs. Edison Accumulators, Limited, 15, Upper George-street, Edgware-road, London, W. 1, inform us that copies of this pamphlet can be obtained by engineers and all others interested, from them and not from Electricars, Limited, as previously stated.

OIL AND PAINT BULK STORAGE PLANT FOR THE FURNESS SHIPBUILDING CO.

CONSTRUCTED BY THE DOWSON AND MASON GAS PLANT COMPANY, ENGINEERS, LONDON.

(For Description, see Page 632.)

Fig 3.

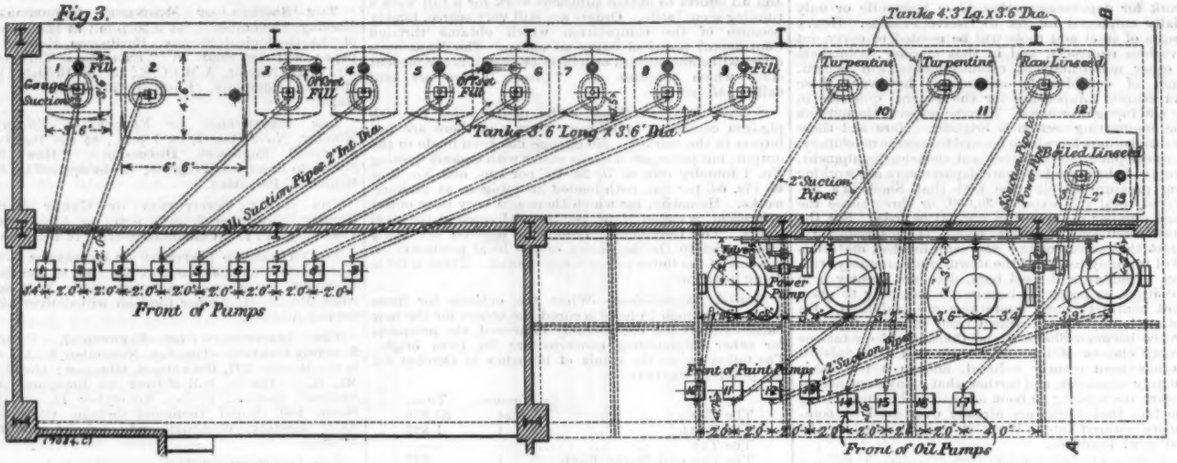


Fig. 4.

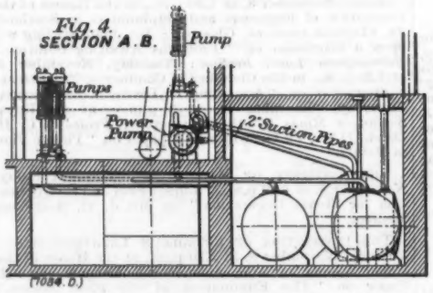
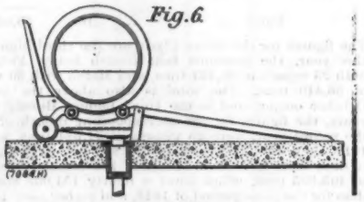


Fig. 6.



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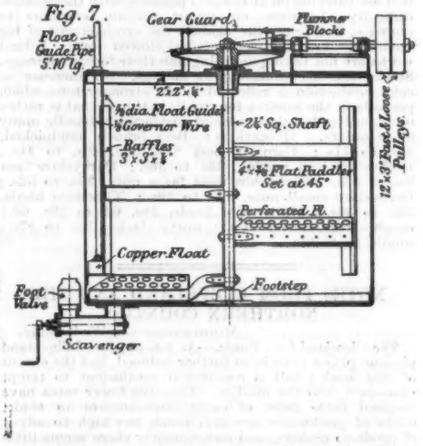

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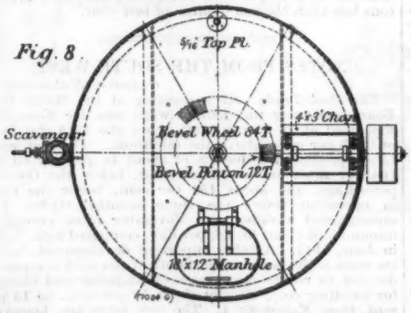

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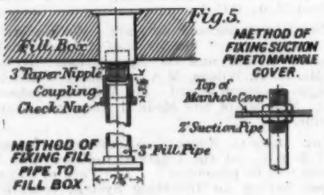


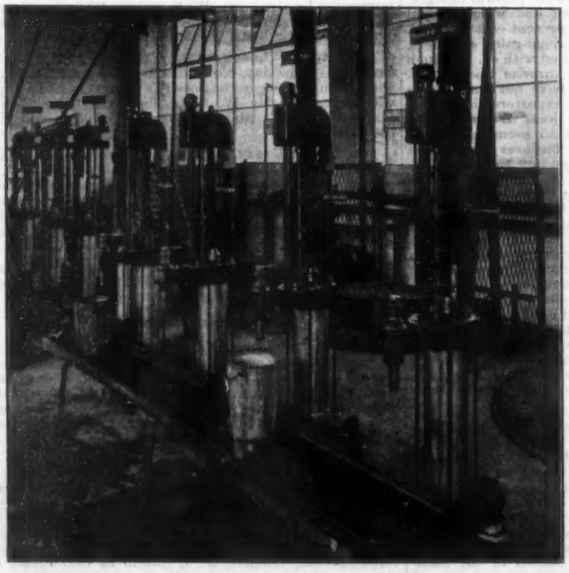


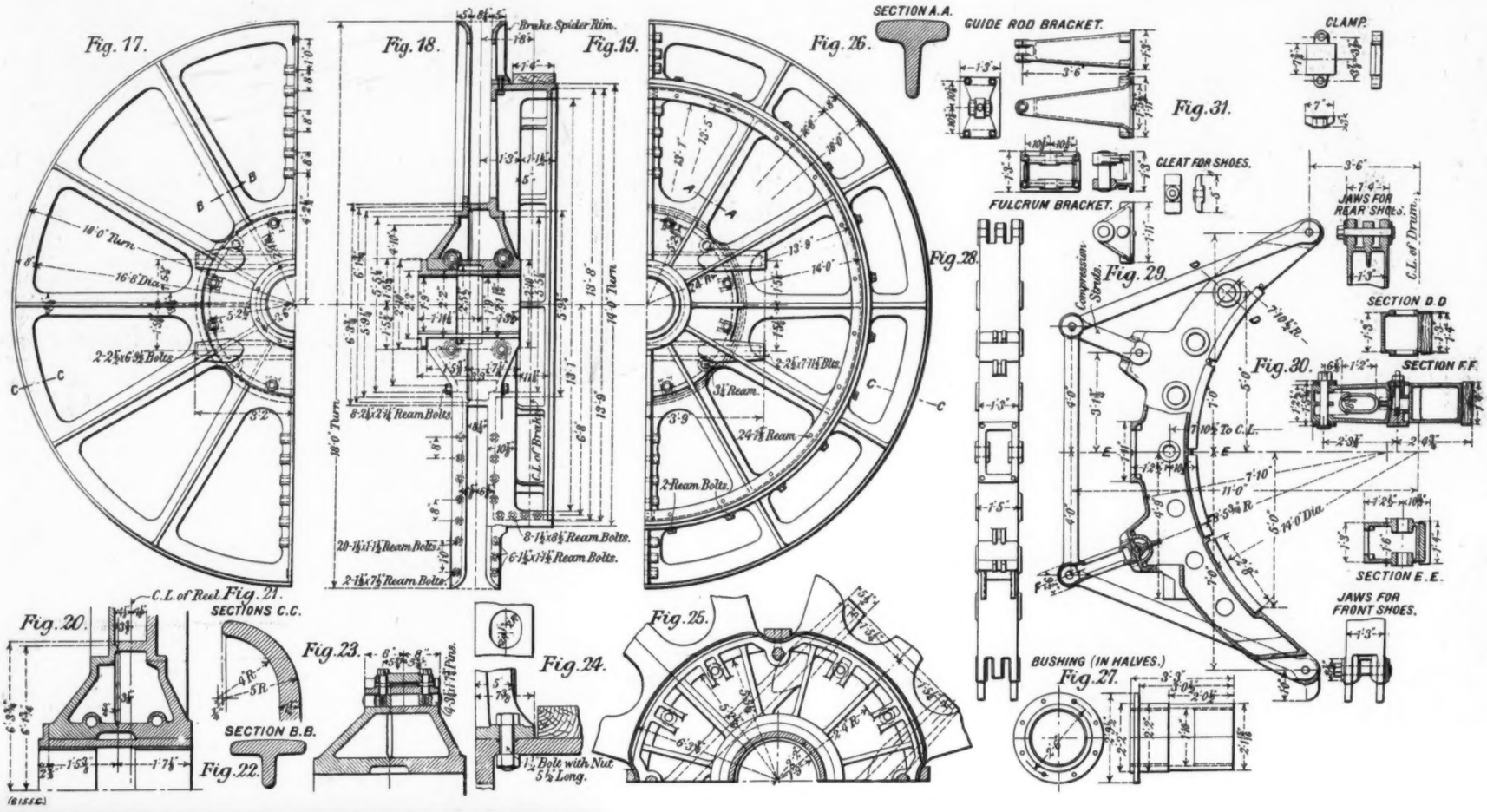
Fig. 9. Paint and Oil Measuring Pumps.

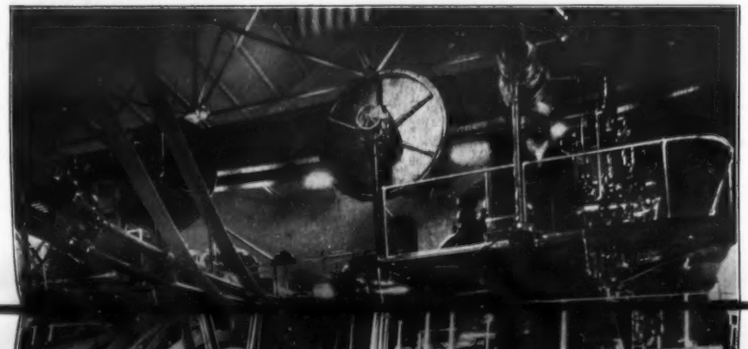
Fig. 10. The Paint Mixers.

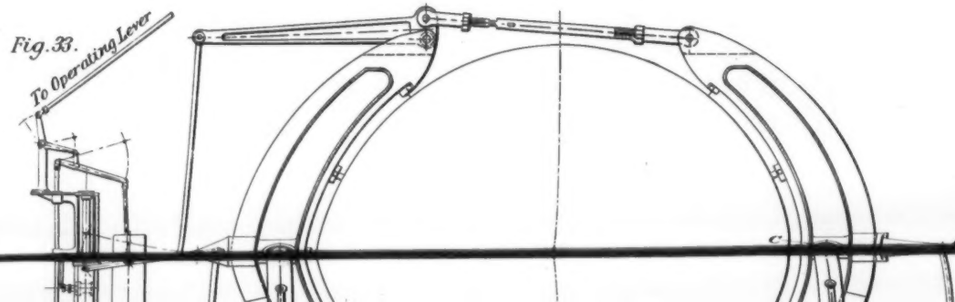
DETAILS OF COMPOUND WINDING ENGINE FOR THE HOMESTAKE MINING COMPANY.

CONSTRUCTED BY THE NORDBERG MANUFACTURING COMPANY, MILWAUKEE, WIS., U.S.A.

(For Description, see Page 628.)







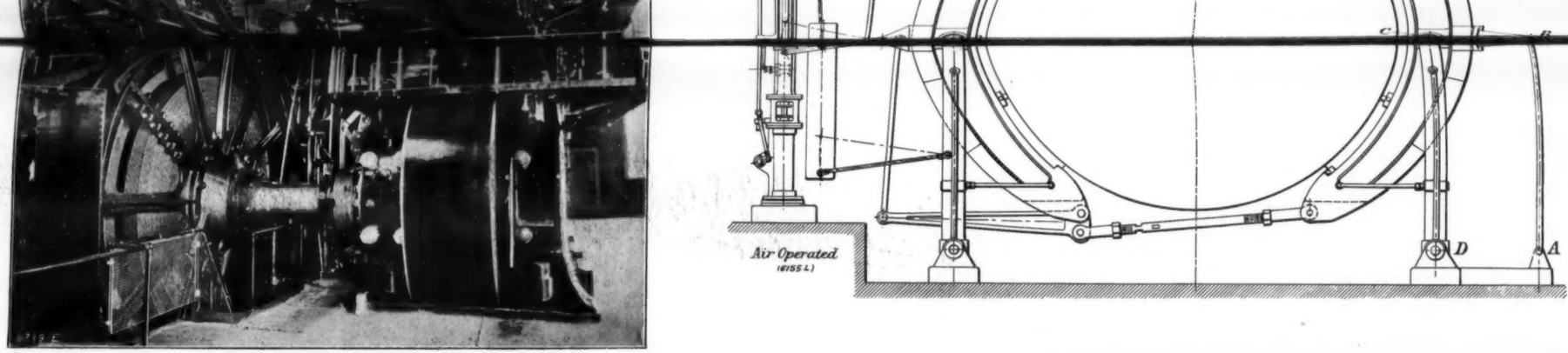


FIG. 32. VIEW OF ENGINE SHOWING ROPE REEL.

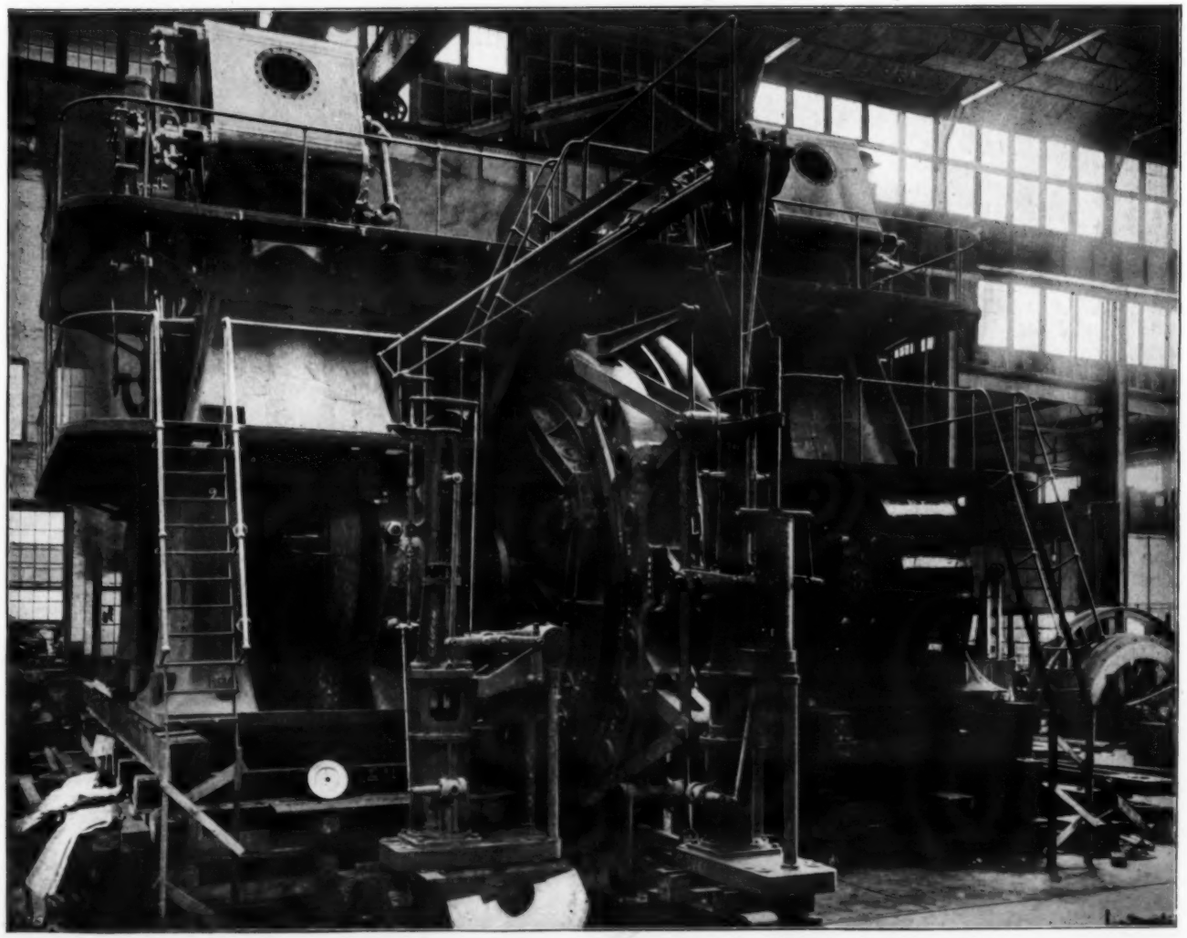


FIG. 34. ENGINE UNDER ERECTION, SHOWING BRAKE AND SERVO MOTORS.

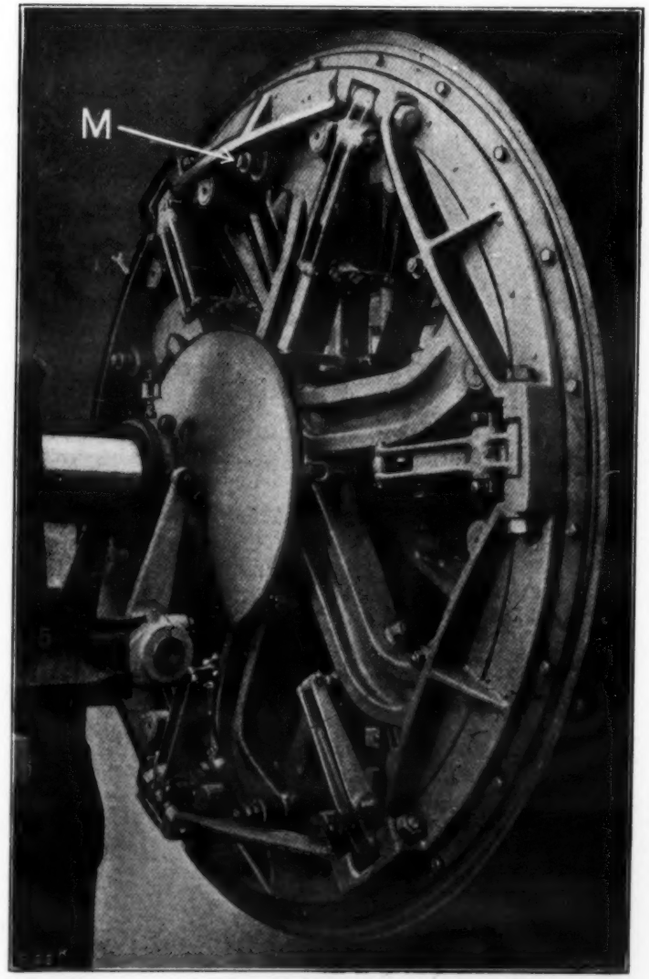


FIG. 35. REEL CLUTCH.

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The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12s. per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

SUBSCRIPTIONS, HOME AND FOREIGN.

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"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

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For Canada—			
Thin paper copies	£2	18	6
Thick paper copies	£3	3	0
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Thin paper copies	£3	3	0
Thick paper copies	£3	7	6

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When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

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TELEPHONE NUMBERS—3663 and 8598 GERRARD

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With a Two-Page Plate of the DETAILS OF COMPOUND WINDING ENGINE FOR THE HOMESTAKE MINING COMPANY.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 633.

ENGINEERING.

FRIDAY, NOVEMBER 4, 1921.

THE CIVIL ENGINEER.

THAT engineering continues to be an art rather than a science is a legitimate deduction, from the importance attached to practical experience, in the able and interesting presidential address which Mr. William Barton Worthington delivered to the Institution of Civil Engineers on Tuesday evening last and reproduced by us on page 646 of our present issue. Mr. Worthington directed special attention to the importance of maintenance work and to the influence which experience in repairs and renewals exercises on the design of new structures or appliances. Occasionally, no doubt, such work calls for the exercise of the highest powers of imagination and executive skill, but when these circumstances arise the work is apt to be so strenuous as to preclude the over-wrought and harassed engineer from properly appreciating its inherent interest. The experience gained in such work is, however, simply invaluable, and many engineering catastrophes may be traced to the lack of such training on the part of structural designers.

Of late years far too many engineers have been reluctant to admit that an empirical factor is involved in fixing the scantlings of roof and bridge members, and have been prone to assume that a knowledge of stress analysis is all sufficient for the proportionment of bridges, roofs and cranes. One result has been such discreditable failures as the collapse of the giant cranes provided for the Panama Canal. A maintenance engineer learns much that he could never acquire in the office. Loose rivets or buckled plates will teach him, for example, that the stiffening of a member is on the border line of danger, a fact which the office man may learn only through a complete and possibly disastrous failure. Amongst the points now specially attended to as the result of experience Mr. Worthington noted the care taken to provide that all steel work not permanently protected from the action of air and damp shall be readily accessible for painting.

Though in some minor details of this kind the designs of our railway pioneers have proved defective, the really astonishing point is the extraordinary endurance shown by structures they built at a time when the weight of a complete locomotive was in some cases less than that now concentrated on a single axle. Of course, many bridges have had to be completely replaced, and Mr. Worthington noted in particular the laminated timber arched viaducts introduced by Joseph Locke on a number of railways, for which he was responsible. Ultimately all of these had to be replaced after a life of from 16 to 28 years, whilst some stone arches of similar span erected at about the same time by Vignoles are still in use, and at the most have needed nothing more than the strengthening of the spandril walls against the pressure of the filling. Mr. Worthington in this connection raised the difficult question as to whether it would not have been better to have avoided the use of non-permanent materials in the first instance, and from the purely actuarial standpoint the answer would, no doubt, be in the affirmative. The matter is, however, not to be settled so simply. In the United States, for example, the community was confronted with the alternative of having either cheap railways or no railways, and very wisely accepted the former, in spite of the attending drawbacks of large charges in subsequent years for maintenance and replacements.

Mr. Worthington has an hereditary interest in the old timber bridges above referred to, as his father worked much overtime on the designs, on various occasions not getting away from the office till ten or twelve at night. With so little precedent to serve for guidance, work of this character must always have necessitated long hours of arduous thought, and, in fact, the same remains true of every really new development in engineering where success is, in general, only attained by heavy toil done out of ordinary office hours. In one respect the engineers of the period in question had an advantage over those engaged in corresponding work to-day. The labour problem was less insistent. The proletariat had not had time to forget the hardships and constantly recurrent famines of the pre-capitalist period, and so far from regarding as natural enemies those engaged in developing the resources of the country, are reported in more than one instance to have offered a week or a fortnight's work free, when the alternative was the immediate abandonment of an enterprise on the verge of success. To-day, whilst confronted with technical problems quite as complex as those solved by our pioneers, the engineer has to devote about half his time to labour difficulties, and in some callings—in particular, that of mine manager in the northern area—there have been repeated cases of nervous collapse from the resultant overstrain.

No doubt in the old days too little consideration was given to the human element in industry, and labour was dealt with almost as if it were a mere commodity. That this condition of affairs has disappeared is a gain, but the pendulum has swung too far in the opposite direction. Grievances either imaginary or, at the most, providing an occasion for a conference or a compromise have been made the excuse for disastrous strikes, which by the consequent destruction or non-creation of wealth have necessarily lowered the average standard of living of the commonalty. At the same time they have greatly increased the burden on the engineer.

We have heard a power station superintendent declare that the troubles consequent on the coal strike lopped ten years off his life. His stokers struck rather than handle Belgian coal, and the whole tramway service of a large area was threatened with a stoppage in consequence. The service was, however, maintained, but, as is usual, the general public knew nothing of the man to whom they were indebted for salvation from such serious inconvenience. No doubt where an undertaking is in private hands labour of this kind not infrequently receives some special recognition by the directors and shareholders, but in the case of a municipal undertaking there is more than a possibility that the engineer's sole reward will be a sense of duty done, which may be largely offset by the fear that this will, by one or other of the various political parties, be counted against him for unrighteousness. Mr. Worthington referred in his address to how little show the engineer makes in the public eye, but this is an old story.

In the United States matters—according to Mr. Waddell—are at present as bad, if not worse, than here. Mr. Worthington, in one part of his address, observed that civil engineering cannot be thrust upon a man, but according to Mr. Waddell this has actually occurred in America, where a lawyer was appointed State Engineer on the ground that the office must be held by a competent politician. Between the modes of thought of the average politician and the engineer there is a gulf as great as that between the mentalities of Jubal and Tubal Cain. The former, we are told, sang of the impassable seas, which Tubal Cain forthwith proved to be non-existent by inventing the boat, to the great annoyance of the discredited seer.

Mr. Worthington devoted a substantial portion of his address to tracing the history and development of the Institution of which he is now the President, and his remarks will be read with great interest and deserve special attention at the present time, when the real objects of an institution of this kind and the best methods of securing those objects do not seem to be properly appreciated by all classes of members.

In dealing with the highly important subject of the education of an engineer, Mr. Worthington touched lightly upon the excellent scheme for training engineers, which has been devised by the Midland Railway Company. Here both pupils and ordinary apprentices are taken into the mechanical engineer's department. From neither class are fees demanded, but the more promising of the ordinary apprentices are promoted to a class of privileged apprentices, who are accorded the same

facilities as the pupil class. This plan seems to get over the difficulty to which Mr. Worthington referred, viz., that under the ordinary premium pupil system only those fairly well endowed with worldly goods can acquire experience in the different branches of engineering work, and thus effectively fit themselves for promotion to the more important posts.

SOME TURBINE BLADING TROUBLES.

A PAPER read before the Institute of Metals in 1915 by Mr. W. B. Parker drew attention to the fact that builders of turbines of a type involving the use of high steam speeds were not wholly satisfied with the blading materials then available. The disastrous results ensuing from the adoption of materials inappropriate to particular types of turbines were vividly exemplified in a paper read before the South African Institution of Engineers by Mr. A. Fenwick in 1917, and reprinted in our issues of May 4 and May 11 of that year. In this paper, illustrations were given of the extraordinarily rapid destruction of the blades of the many large steam turbines of German manufacture and design installed at the power stations of the Rand Power Companies. Similar unsatisfactory experiences have been recorded in China and in Australia with turbines of similar provenance, thus indicating that the builders had started to supply the market before they had adequately tested their designs. It is not, in fact, an easy matter to determine the suitability of a material by laboratory tests. In the early days of steam turbine construction a leading Continental firm experimented with two steels. Of these the one as tested in specimens measuring 30 mm. by 30 mm. in section and 100 mm. long showed an elastic limit of 22·2 tons per sq. in. to 26·7 tons per sq. in., a tensile strength of 40 tons per sq. in. to 44½ tons per sq. in., and a reduction of area of from 30 per cent. to 45 per cent. Tested in the Fremont machine, specimens measuring 10 mm. by 8 mm. absorbed 35 kilogrammetres to 36 kilogrammetres of energy without being completely broken in two. The other steel used, when tested in tension, showed an elastic limit of 25½ tons per sq. in. to 31¾ tons per sq. in., a tensile strength of 38 tons per sq. in. to 44½ tons per sq. in., but the reduction of area was only 15 per cent. to 20 per cent., and in the Fremont tests the bars were completely broken in two with an absorption of energy varying from 15 kilogrammetres to 20 kilogrammetres. Of the two steels the first contained 25 per cent. of nickel and proved quite unreliable in service, whilst the other was a 5 per cent. nickel steel and was satisfactory. In this instance, at any rate, the Fremont test was evidently misleading, and it would be of great interest to know whether the Sankey testing machine would have given any better indication of the respective trustworthiness of the two materials. This latter test is one in which we have considerable faith, since it is merely a systematisation of the methods of testing which have been used by workers in iron since the dawn of history. It may quite well be, however, that the test would have failed in this instance, as the failure of high per cent. nickel steels when used for turbine blading has not yet been satisfactorily elucidated.

In the discussion on Mr. Parker's paper, Admiral Oram stated that they had had very little trouble with blading in the Navy, and Sir George Goodwin has recently stated that this excellent record is still maintained. It must, however, be borne in mind that not only are turbines in the Navy seldom run at full power, since cruising speeds can be maintained with a mere fraction of the maximum power, but moreover steam speeds generally rule lower than on land. Experience shows that this point is of very great importance. Some few years back, for example, an exhaust steam turbine was constructed as a single stage velocity wheel. The blades were of a 70-30 brass and were cut to pieces by the steam in the course of a fortnight's work. This wheel was then replaced with a short drum carrying a few rows of reaction blading of the same material. The tip speed of the longest row of blades was 500 ft. a second. With the reduction in steam velocities consequent on this reconstruction of the turbine, the excessive wear disappeared.

From the paper by Lieutenant-Commander D. F. Ducey, U.S.N., of which we complete the publication this week, it would seem that the American Navy has been less fortunate than our own. We understand that the impulse turbines in our Navy have in general been equipped with phosphor-bronze blading, whilst from the paper quoted it appears that in the United States chrome nickel steels have been somewhat extensively employed. No doubt the engineers responsible had satisfied themselves by the usual laboratory tests of the suitability of this material, but as has often happened on this side of the Atlantic the ordinary laboratory tests have turned out to be fallacious. The photographs of the damaged blades recall those reproduced in our issues of May 4 and May 17, 1917, representing blading taken from the German turbines in South Africa, and would appear to indicate that the material is not suitable for turbine blading. At least this is the conclusion, which we ourselves would draw, but Lieutenant Commander Ducey is, we gather, of a different opinion, though he reports that the material requires extraordinary care in use. Thus he observes that each and every blade must be true to designed shape, otherwise in attempting to install the blades, deformation of blades will take place. For our own part we feel that an alloy which will not withstand such small adjustments as it may be called upon to endure in ordinary workshop practice is hardly an engineering material, and whilst possibly of value for special purposes to the instrument maker, should not be admitted to the interior of a turbine. This view is only emphasized by the additional recommendation made that each and every blade should be examined under a magnifier for cracks before being passed for use. We cannot think that the solution to the difficulties described in Lieutenant Commander Ducey's paper is to be found in this direction, but that either a different metal must be used, or the design of the turbine modified so as to avoid the necessity for adopting materials which have not passed the proof of actual service. Of course, if no new materials are ever to be experimented with, progress would cease, but the experiences in South Africa and elsewhere indicate that at the outset the introduction should be tentative only, and extended later only as experience thus obtained justifies the step. We must confess, however, that even when this policy is adopted, safety is not always secured. The first impulse turbine built by a certain British firm had 32 per cent. nickel steel blades and never shed one. Subsequent experience with the same material was, however, most unsatisfactory, strips being so frequent that another material had to be substituted. Continental builders of the same type of turbine suffered similarly from strip after strip, until the use of the high nickel alloy was abandoned. Strips are, however, not always due to the use of unsuitable materials. In the early days of the so-called disc and drum machines, the velocity wheel stripped more frequently than any other part of the turbine, and the defect was only overcome by re-designing the roots of the blading so as to secure greater strength there.

MODERN WIRELESS TELEGRAPHY.

THE address delivered by Mr. A. A. Campbell Swinton, F.R.S., on Wednesday last, at the inaugural meeting of the 168th session of the Royal Society of Arts, although of undoubted interest to those members of his audience who were unfamiliar with modern developments in wireless telegraphy, must suffer considerably by being recorded in print, since it actually took the form of an experimental demonstration. The lecturer dealt mainly with the various methods of recording wireless signals, and first illustrated a number of photographic records obtained by means of a sensitive manometric flame, or by delicate mirror galvanometers, before the science had been revolutionised by the introduction of the three-electrode thermionic valve. He afterwards showed a modern record he had himself obtained from a powerful continuous-wave station by means of a syphon recorder, and also a printed record obtained in the Society's lecture hall last year from the Eiffel Tower station in Paris, by means of the Creed apparatus.

The reception of Morse signals and telephony from the lecturer's office in Victoria-street, using a power of 10 watts in the transmitting aerial, was next shown, the signals and human voice being rendered audible in the lecture hall by means of a "Magnavox" loud speaker. A set employing four or five valves was used for this reception, but the lecturer did not refer to the nature of the apparatus. Considerable stress was laid by the lecturer on the utility of recording Morse signals by means of a phonograph, a number of records obtained in this way being reproduced. Such records can, of course, be run off at a much slower speed than that used in the original transmission, so that they can be deciphered by a less experienced operator. Moreover, any portion of the message not understood can be repeated. Music transmitted from Blackheath by Mr. W. W. Burnham, using a wave-length of 230 m. and a current of 1·2 amperes in the transmitting aerial, was very successfully received, and some of this was recorded on a phonograph cylinder and afterwards reproduced. An attempt to receive the weather report from Nantes on a frame aerial in the lecture hall was not completely successful, since although the message was audible to the lecturer and his assistants it could not be heard in the hall.

Mr. Campbell Swinton then briefly outlined the method of determining time with a high degree of accuracy by means of the scientific time signals sent out from the Eiffel Tower. These are received in the form of ticks, the interval between which is $\frac{5}{6}\frac{5}{6}$ of a second. By noting the number of the ticks which coincide with the ticks of a seconds pendulum at the receiving station, it is possible to determine the time at which the coincidence occurred with an error of less than $\frac{1}{2}\frac{1}{5}\frac{1}{0}$ second, since the exact times at which the beats commence and finish are afterwards transmitted by ordinary code. The lecturer's demonstration of the method was, however, unfortunately rendered ineffective by the fact that a message was being transmitted from Poldhu on an approximately equal wave-length. The final demonstrations of the use of the Johnsen-Rahbek effect, both in magnifying the sound of the human voice as well as that of wireless signals received in the room, were particularly striking, but for an explanation of the principles involved we must refer our readers to an article which appeared on page 685 of our last volume. Sir Oliver Lodge, who was present at the lecture, proposed a hearty vote of thanks to Mr. Campbell Swinton.

THE RECONSTRUCTION OF THE FRENCH DEVASTATED REGION.

WE dealt in our last volume with the war devastation of Northern France as far as the mines, steelworks and railways were concerned, and pointed out in our articles the share which the invaded and devastated regions had in the total French output and production of a number of mineral products and industrial specialities. We were not in a position to fully describe at the time the work of reconstruction carried out by France. This work formed the subject of a lecture delivered by the Marquis de Chasseloup-Laubat last Wednesday, at an extraordinary meeting of the British Section of the Société des Ingénieurs Civils de France, held at the Institution of Mechanical Engineers. The meeting was presided over by Mr. Raymond Poincaré, Past President of the French Republic.

The proceedings were opened by Mr. T. Guéritte, the president of the British Section, who said it was superfluous to introduce Mr. Poincaré, whose name was known and respected in every hamlet in England as in France. He thanked Mr. Poincaré on behalf of the section for the great honour he had conferred upon it in consenting to occupy the chair.

Mr. Poincaré, in declaring the meeting open, thanked the British Section for so kindly inviting him and giving him the opportunity of listening to the Marquis de Chasseloup-Laubat. He (the speaker) represented in the French Senate one of the Departments of France which had been devastated, and he knew well what that word meant; he also knew the efforts which had been made by engineers in making good the destructions, and felt very grateful for their generous help. Much had

already been done from the point of view of the industries of those regions, but very much still remained to be done, notably in regard to private houses and the dwellings of the peasantry. Ruins were still to be seen everywhere, and the goodwill of everybody was still needed; the sorely tried provinces were deeply grateful to the engineering profession for their scientific aid and devotion.

Mr. M. Laubeuf brought the good wishes of the Société des Ingénieurs Civils de France, Paris, and expressed the hope that the formation of the British Section was a first step towards a union of the prominent institutions of engineers in allied and friendly nations. He recalled the services rendered by Mr. Guéritte in the formation of the section; those of Mr. de Chasseloup-Laubat, the hon. treasurer of the Paris Society for the last twenty-five years; and also those of Mr. H. Sloog, the hon. secretary of the section, who, unfortunately, was unable through illness to be present at the meeting. He then referred to the wanton destruction carried out by the Germans in France far from the Front generally and without any military necessity whatever. In order to find similar examples of such utter savagery it was necessary to turn back over a thousand years in the world's history. The German word *Schadenfreude*, which expressed the joy they had in destroying the property of other nations, had no counterpart either in the British or the French languages, no more than the sentiment it gave expression to could be found in British or French mentality. All who visited the devastated districts were unanimous in stating that they had not the least idea that the disasters were so terrible as they found them actually to be. The German indemnity payments were a vital question for France, who had as yet only received a most insignificant amount in comparison with the extent of her losses and the cost to her of making good, so far, the destructions referred to. It was astounding that some people could still be found who expressed pity for "poor Germany"; before pitying her, he (Mr. Laubeuf) thought her victims should be first in the thoughts of everyone. The war left Germany with all her productive capacity: if she did not pay what she owed, France would be ruined, and if a nation was to be ruined owing to the war that nation, in all justice, should be Germany. He felt confident that "our British friends" would remain shoulder to shoulder with France in her claims, and these were dictated by pure and simple justice and nothing more.

M. le Marquis de Chasseloup-Laubat pointed out the difference which existed in the *rôle* of statesmen and of engineers; he thanked all public bodies, their representative members, and ENGINEERING for the aid their efforts had given France in the difficulties with which she was surrounded by reason of deliberate enemy action. He called attention to the share which in pre-war days the devastated regions had in the total activity of the country, and gave the figures which we quoted in our former series of articles. Other figures of his were as follow:—The dwellings in the regions in question numbered 1,204,822 before the war; at the armistice 290,000 were found completely destroyed and 423,000 partly destroyed; at the present time 117,000 are completely repaired and 182,000 partly repaired. The area of cultivated ground destroyed amounted to 5,000,000 acres; 4,000,000 acres have been prepared for cultivation, of which 3,500,000 acres are now under cultivation. The roads destroyed had a total developed length of over 30,000 miles; 10,000 miles are completely repaired and 20,000 are in hand at the present time. We gave in our former articles the length of the Northern and Eastern of France Railways, and described some of the work of destruction to both systems; the French engineers, and very rightly so, gave their attention first to making good the railway damage, and at the present time the tracks, bridges, tunnels and viaducts are in complete working order again.

In the course of a preceding lecture which Mr. de Chasseloup-Laubat delivered in France, in 1901, he gave the sum of 8,000,000,000*l.* as the estimated French wealth of productive sources. If it be reckoned that in the period from 1901 to 1914 this wealth increased by, roughly, 1 per cent. annually, the figure for 1914, at the time of the declaration of war, may be taken as having been 9,000,000,000*l.* in round figures. In evaluating the effects of the war, the lecturer recalled that the French losses in men killed, missing, or rendered incapable of further work by reason of wounds or sickness were a total of about 2,500,000, all these men being cut off in their full strength, and forming one-quarter or one-third of the French productive capacity in man-power. Notwithstanding the accretion of the Alsace-Lorraine population, France had these men the less for cultivating her soil or exploiting her wealth.

Dealing with the balance sheet of material wealth, the gain due to the annexation of Alsace-Lorraine may be put, for the present, at a maximum of probably 1,000,000,000*l.* On the other hand, the losses were: (*a*) The Russian debts and the debts in other parts of Eastern Europe, at least 1,000,000,000*l.*; (*b*) the public and private debts of France towards the Allies and associated nations, probably also 1,000,000,000*l.*; (*c*) the direct and indirect debts due to the devastations carried out in France. These direct losses were about 1,000,000,000*l.*, and the indirect ones probably also 1,000,000,000*l.*, for the latter were much higher than was generally believed. In this connection, it must be remembered that the French Government cannot levy taxes upon the inhabitants in the devastated regions so long as these regions are not reconstructed, hence there arises a considerable loss to the French Treasury; further, another cause of very considerable indirect losses—which generally was never referred to—resided in the perturbations in the economical organism of the nation by the cutting off for a period from the said organism of one of its most important elements. Taking as an illustration an occurrence in everyday life, the lecturer instanced the utter uselessness of a motor car costing probably 1,000*l.* by reason of an accident to, say, the gear-box, a matter of probably much less than 100*l.*

The total losses enumerated above were therefore 4,000,000,000*l.*; by deducting the gain due to the annexation of Alsace-Lorraine the balance became 3,000,000,000*l.* This latter figure being deducted from the French pre-war wealth of productive sources, or 9,000,000,000*l.*, there remained 6,000,000,000*l.* for the present, post war, French wealth of productive sources.

The total amount of taxes now levied in France was 20 milliard francs, equal to about 400,000,000*l.* This latter sum, reckoning upon a rate of interest at 6 per cent., represented a capital of about 6,000,000,000*l.*, equal to the above figure for wealth.

This meant, Mr. de Chasseloup-Laubat pointed out, that France was no longer a capitalist nation. She could rise again from the low situation in which she had been cast only by dint of persistent thrift and strenuous work.

The lecturer then gave parallel figures in regard to the United Kingdom. Before the war, the total wealth of the United Kingdom was estimated at 13,000,000,000*l.* or 14,000,000,000*l.* Her losses in men killed, missing and incapacitated from further work reach a total of 1,000,000 or 1,500,000; the excess of births over deaths had almost made good the difference, reckoning on mere numbers. From the material point of view, the debt of the United Kingdom to the United States had, as a counter-part the debts of France and other continental nations to herself. Besides, England now controlled rich petrol-bearing areas in Mesopotamia. Therefore, by estimating the total losses of the United Kingdom at 1,000,000,000*l.*, one was near the right figure, and the British wealth of productive sources might be taken as 12,000,000,000*l.* The British paid in taxes a total sum which, the lecturer hoped, would not exceed next year 800,000,000*l.* or 900,000,000*l.* This sum, also reckoning upon a rate of interest of 6 per cent., represented a capital approximately equal to the figure for the British wealth. This means that the United Kingdom, the same as France, can only emerge successfully from her difficulties by strenuous work and thrift.

A comparison of these figures showed, moreover, that France, on her resources, paid as much in tax as the United Kingdom, and not less, as was stated erroneously in certain quarters. The only equitable method for estimating the charges made upon the citizen of a nation was not, added Mr. de Chasseloup-Laubat, to calculate these charges per head of the population, but to take into account the total and the average wealth. The fact should also not be lost sight of that France had to face extraordinary expenditure in the reconstruction of her devastated provinces, and in regard to this, owing to the uncertainty of the German payments she was in a state of great perplexity and difficulty. If in order to husband her financial resources she did not reconstruct the said provinces, the French Treasury continued to lose the benefit of the taxes from these same provinces, and her sources of wealth continued to remain partly dried up. If she carried on the reconstruction work she had to borrow, also to increase her taxes, and her exchange would fall lower than it was even now. Such was an accurate statement of her situation.

The efforts made by France at the reconstruction of the devastated regions reacted heavily not only upon France, but also upon the United Kingdom. The present economical crisis showed that the prosperity of France was intimately connected with that of the United Kingdom. The prosperity of one nation was necessary to the life of the other. France owed enormous sums both to the United States and to the United Kingdom; their repayment exceeded the capacity of France so long as her devastated regions were not entirely reconstructed. The problem thus became one which did not interest France alone, but also the United Kingdom, who, the lecturer added, had her own devastated regions, in the shape of empty workshops, and who knew the difficulties surrounding a problem of this kind.

The remedies pointed out by Mr. de Chasseloup-Laubat were threefold: the establishment between the United Kingdom and France of an intimate, effective, sincere and a real Entente Cordiale; by pooling our resources, as he proposed to Lord Kitchener and to M. Cambon on November 12, 1914, the Allies were able to meet the grave explosive crisis which was nearly leading to a loss of the war. By the two nations coming closer together at the present time, by ceasing, for example, to hurl customs tariffs at each other, they would be able to secure the control of an economical crisis which was far more dangerous than all the machinations of the ex-Kaiser and his staff. In the second place, it was necessary to work more than was now done—to work both harder and longer hours. Finally, economy both by individuals and by Governments must be carried to the extreme. Every individual and national resource must be set apart for useful work—work such as the reconstruction of the French devastated regions, the common burying ground of a very large number of both British and French citizens.

Mr. Poincaré, in closing the meeting, thought he rightly expressed the feelings of all present in warmly thanking Mr. de Chasseloup-Laubat for his interesting exposition. This had been too short in comparison with the extent of the subject dealt with, and very many more views than those which had been shown on the screen would be required to truly depict the vastness of the frightful depredations caused by the enemy. These were being made good every day, but an enormous amount of work yet remained to be done. In regard to this restoration work, France was odiously calumniated, not by any mean German journal or personality, but by Herr Simons himself, who told an American Representative that France was deliberately delaying that work. Mr. Poincaré called attention to the absolutely wilful and needless destruction of such towns and places as Rheims and its historical cathedral; St. Quentin, from which absolutely every bit of machinery was carried away or broken up; Lens, where practically no trace of the collieries and other buildings remained—among thousands of other instances which he could name—and Germany expressed astonishment at France demanding the coal from the Saare as part compensation! The most pitiful picture was that still afforded by the country places as distinct from the towns; not one of the numerous villages which formerly surrounded Verdun was standing; ruins were everywhere. There was still a zone, called the

"red zone," in which unexploded shells were still so numerous, both above and underground, that accidents were much to be feared. Herr Simons had also stated that the French peasants were not desirous of returning to their devastated farms, preferring to remain in places where living was easier to them; that was utterly false, for the peasants had returned to their former lands, although they had to live in huts, tents and cellars, while others were eager to return and would return as soon as steps for their security taken by the State would enable them so to do. He thanked the French Society and its British Section for their co-operation in the restoration work, and in conclusion emphasised the urgent importance to France and to all other nations of Germany discharging her obligations and also disarming.

THE BREWERS' EXHIBITION.

Although in the past year the changing and unreliable conditions that have affected all industries have certainly been felt in the brewery and allied trades, the character of the exhibition which opened at the Royal Agricultural Hall on Friday last, and closes to-day, seems to indicate that that particular industry is by no means in despair as to the future. The exhibition is larger and more complete than that of last year, both as regards products and plant, and although new appliances are not in evidence to a striking extent, they are sufficiently numerous to indicate that steady progress is being made. As usual at these exhibitions, machines for washing, filling, corking and labelling bottles form a very large proportion of the exhibits of mechanical appliances. Such machines, in fact, are shown at nearly twenty stands, but as our space is limited and most of them are already well known to the trade, we do not propose to deal with them on this occasion. Moreover, many of the machines were referred to in our article* describing last year's exhibition.

A striking feature of the exhibit of Messrs. G. J. Worssam and Son, Limited, of Wenlock-road, London, N. 1, is a fine example of coppersmiths' work in the form of a large fire-heated brewing copper, the capacity of which is 225 barrels. Brewing coppers are, however, often heated by steam, and a steam-heating element suitable for the purpose is also shown. This is composed of a copper cylinder mounted vertically on three feet near the bottom of the copper, and fitted with tubes through which the liquid can circulate. Steam is supplied to the body of the cylinder through one of the feet, and the condensate is drained away through another. A new appliance at Messrs. Worssam's stand is a centrifugal machine for extracting beer from yeast. The process is continuous, the liquid yeast being fed into the top of the machine and discharged at the bottom in the form of a stiff cake without stopping the machine. The beer separated is fairly clear, but to clarify it completely, the few remaining yeast cells can be removed in a small high-speed centrifuge. Examples of the firm's standard products, which include malt mills and screens, refrigerating plant, centrifugal pumps, &c., are also shown.

The chief exhibit at the stand of Messrs. H. J. West & Co., Limited, 72-74, Gray's Inn-road, W.C. 1, is a high-speed ammonia compressor of the type illustrated and described on page 507 *ante*, to which we must refer our readers for full particulars. The actual compressor shown has a refrigerating capacity of 30 tons, and is driven by a direct-coupled oil engine by Messrs. Vickers-Petters, Limited. Another interesting exhibit is a small self-contained CO_2 refrigerating plant suitable for butchers' shops. The compressor is mounted on the condenser and driven by a direct-coupled electric motor of 2 h.p. The overall dimensions of the plant are only 4 ft. 4 in. long by 1 ft. 2 in. wide and 3 ft. high, but it is capable of cooling a storage chamber of 1,200 cubic ft. capacity, or of producing 10 cwt. of ice in 24 hours. We hope to deal more fully with this plant on a future occasion. Messrs. West also showed a complete bottling unit, including soaking, brushing, rinsing, drying and filling machines, as well as gravity conveyors and a model of a special elevator for raising or lowering crates, barrels, bales, carcases, or other forms of merchandise from one floor to another. In this, a crate is delivered to the elevator on a short section of gravity conveyor, and is picked up from this by a telescopic arm attached to the elevator, raised or lowered as required, and deposited on to another gravity conveyor on a different floor. The telescopic arms run in a channel-iron guide, shaped so that the arms are extended and withdrawn at the right points to pick up or deposit the goods. In handling carcases, ordinary meat rails are used in place of the gravity conveyors.

The large barley-sweating drum described in our article on last year's exhibition, again formed a striking feature at the stand of Messrs. R. Boby, Limited, of Bury St. Edmunds, who also showed examples of their well-known products such as malt mills, barley cleaners and malt cleaners. A small pneumatic grain-handling plant capable of dealing with from 20 to 25 quarters per hour was also shown in operation, to demonstrate the action of the larger plants constructed by the firm. One of these plants supplied to Bordeaux was illustrated and described in our columns on pages 312 and 370 *ante*.

Maltsters' plant is also shown by Messrs. George Porteus & Sons (Leeds), Limited, of Leeds, whose exhibit include examples of their latest designs of eight-roller and four-roller malt mills. In these, the malt is first crushed between a pair of upper rollers and then falls into a cylindrical sieve, or detacher as it is called, which separates the fine grist, or semolina, from the bulk. The remainder passes into a second detacher, which separates the husks and hard ends, the former passing on with the fine grist from the first detacher. The coarse grits and hard ends are delivered on to another pair of rollers, which reduce them to fine grist, and all the products combine and leave the mill at the bottom. It is claimed that this process gives fine even grist with the minimum of flour and with practically whole husks, which are important considerations in brewing. Another simple, but useful, appliance shown by Messrs. Porteus is a small cask washer, in which the cask is placed on a cradle so arranged that a nozzle passes through the bung hole. Steam and water, either separately or together, are admitted to the cask by means of a single lever controlling valves on pipes connected to the nozzle. While this is being done the cask is set spinning by hand, the cradle being mounted on ball bearings so that it runs very easily. The steam and water thus reach all parts of the interior of the cask and thoroughly clean and sterilise it. More elaborate cask-washing plant is shown by Messrs. G. Hopkins & Sons (Clerkenwell), Limited, 40 to 52, Holloway-road, N. 7, but this firm's exhibit does not differ materially from that of last year.

The Farringdon Works and H. Pontifex & Sons, Limited, display chilling plants, filter presses, refrigerating plant and bottle-washing apparatus, but the only new product we noticed at their stand was a 24-head filling machine. In this the bottles travel on a band conveyor which automatically places them under the filling heads. When in position, the bottle is raised by a plunger so as to make a gas-tight joint with the filling head, and gas is first admitted to raise the pressure in the bottle up to that in the container. A valve then opens to admit the beer, and the bottle is filled quietly without frothing. When filled, the bottles are automatically removed on the band conveyor. The machine can fill 220 dozen quart bottles per hour.

The Wolfe Keene Engineering Company, Limited, of Bridge Works, Bristol, show a new machine for continuously separating barm from beer, and delivering it in a form suitable for transport or re-use in the brewery. In this machine the beer is run into a trough in which rotates a perforated drum covered with a suitable fabric filtering medium. The beer is drawn through the drum by means of a suction pump, leaving the yeast on the surface of the filtering medium, from which it is removed by a scraper as the drum rotates. It is pointed out that since the barm is only subjected to low pressures, no bursting of the yeast cells occurs and the flavour of the beer is therefore unaffected.

It is, of course, of the utmost importance that materials which do not affect the flavour of beer or interfere with the delicate biological process of fermentation should be employed in breweries. Aluminium has been found to be very satisfactory in these respects, and the Aluminium Plant and Vessel Company, Limited, of Wandsworth, S.W. 18, have constructed a large number of vessels for brewing operations. Their exhibit includes a cylindrical tank for bulk transport capable of holding 720 gallons, and intended to be mounted on a motor lorry. The weight of the tank alone is 3½ cwt., as compared with 10 cwt. to 12 cwt., which would be the weight of a similar tank constructed of steel or copper. A number of vessels for Scott's yeast-pressing process are also shown together with a Yorkshire tray, which is used in fermenting vessels to retain the gases. The tray is in the form of a shallow dish, about 8 ft. in diameter, with a central hole 2 ft. in diameter, and is made from ⅛ in. plate. All the vessels have welded joints which are practically invisible and are produced by a patented process.

Steel tanks lined with vitreous enamel are also largely employed in breweries, and these are shown by the Enamelled Metal Products Corporation, Limited, Kingsway, W.C. 2, Messrs. Butlers (London), Limited, Minories, E. 1, and by Messrs. J. Thompson (Wolverhampton), Limited, Ettingshall, Wolverhampton. The latter firm also exhibit lead-lined tanks and models of their other products which include water-tube and Lancashire boilers, and Kennicott water softeners.

Although a number of firms exhibit barrels and casks, some of which are fine examples of the cooper's craft, we only noticed one firm displaying cask-making plant, viz., Messrs. A. Ransome & Co., Limited, of Newark-on-Trent. This firm show a belt-driven machine for driving the hoops on casks. In this, the driving arms which engage with the hoops are pivoted on the periphery of the driving head and the latter is forced downwards, so as to drive the hoops home, by means of a rack and pinion gear. The machine, we understand, will drive the six hoops on each of three standard 40 gallon barrels in one minute. A combined power driven hoop punching and riveting machine is also shown by this firm. Messrs. James Stewart & Co., of Edinburgh, show branding and washing machines for casks, as well as a hand-power hoop cutter and a shive-turning machine. Their exhibit is, however, practically the same as that of a year ago.

The only other items likely to interest engineers are the steam and electric lorries suitable for the heavy transport work of breweries. Steam wagons are shown by Messrs. Fodens, Limited, Sandbach, the Sentinel Wagon Works (1920), Limited, 14-16, Grosvenor-gardens, S.W. 1, Messrs. Wm. Allchin, Limited, Northampton, Messrs. R. Garrett & Sons, Limited, Leiston, and Messrs. Ransomes, Sims & Jefferies, Limited, Ipswich. The two last-mentioned firms show electric lorries in addition, and the General Vehicle Company, Limited, 43, Shoe-lane, E.C. 4, also show a vehicle of this type. The only petrol-driven lorry we noticed is exhibited at the stand of Messrs. Henry Garner, Limited, Birmingham.

* See Vol. CX, page 610.

NOTES.

The Electricity Commissioners' Report.

Although very much remains to be done, particularly in a financial direction, towards the co-ordination of electricity supply in this country, the appointment of the Electricity Commissioners has resulted in a useful beginning. The various inquiries into the formation of electricity districts have not as yet in general led to very positive results, but in many areas the ground has been cleared and a better general idea of what is required has been disseminated. It is evident that much educative work must be done before the co-ordinated ideal which is aimed at can be realised in complicated districts in which there are very many independent interests and points of view. Apart from the question of the formation of Joint Electricity Authorities, the duty of the Electricity Commissioners cover the granting or withholding of permission to

build new generating stations, to extend supply outside statutory districts and similar cognate matters. They also control the voltage, periodicity, &c., of new installations. A study of the first annual report of the Commissioners, which deals with their activities down to the end of last March, and which was published a few days ago, shows that these minor duties cover a large amount of work, and that very many matters of this kind have been dealt with and determined in the period under review. The Commissioners' work in connection with the formation of Joint Electricity Authorities is naturally of the greatest general interest, but down to the date covered by the report no matters of this kind had reached a determinate stage, so that in this sense the publication is disappointing. As a record of the beginning of an important work it is, however, of interest and value, while its use for the purposes of reference is increased by the review of electricity supply from 1882 to 1919, with which it opens.

Water Power Resources of the Empire.

The Final Report of the Water Power Committee of the Conjoint Board of Scientific Societies, issued during the past week, deals very briefly with some of the countries within the Empire in which important resources in the form of water power are available. It will be remembered that a preliminary report was issued by this Committee in 1918. An interim report was issued in 1919, and a second interim report followed last year. The latter suggested the appointment of a Board of Water Commissioners for the control and allocation of water supplies in Great Britain. The final report now issued is not so interesting for the condensed information it gives on the resources of some parts of the Empire, which have, as a matter of fact, been frequently discussed of late, as for the recommendation, suggested in the first report and now enlarged upon, for the formation of an Imperial Water Power Board. The Committee points out that taking the Empire as a whole no attempt is being made to make an inventory of the resources available, and that some of the smaller sections could not go to the expense which such work would involve. The proposed Board would include representatives of the Dominions and Dependencies, and its object would be to investigate and subsequently disseminate information regarding the resources of the whole Empire, with a view to their development in the most advantageous manner. It should, the Committee thinks, be possible for enterprises to be able to apply to some such body for reliable data in connection with industrial developments needing cheap power. At present no assistance of this kind is available, with the result that the resources are either not being developed at all, or are being brought into use on haphazard and ill co-ordinate lines. The Board would, of course, need a permanent staff and funds if it were to prove of service. Owing to the Water Power Committee lacking both these it considers its services have reached their limit. An Imperial Water Power Conference is also proposed to be held in London at an early date. Such a conference has, as a matter of fact, been provisionally supported by some of the parts of the Empire concerned, and if one were held, the opportunity would be suitable for the further discussion of the proposal for the Imperial Board and other matters, such as uniformity of methods of investigation, &c.

The Work of the Electrical Research Association.

The September quarterly progress report of the British Electrical and Allied Industries Research Association, which was issued a few days ago by Mr. E. B. Wedmore, the Director of Research, indicates that a very extensive programme of work is in hand. The work of the Association is conducted by committees under eleven sections, the activities of many of which have reference to the properties of insulating materials. This is a direction offering a very extensive field for the type of investigation which can only be effectively undertaken by a body properly organised for a detailed and extensive research, and one may expect that the ultimate results of the work in hand will be of considerable technical and commercial importance. Investigations are being made of the properties of fabrics, papers, fibres, composite insulating materials, porcelain, mica, insulating oils and synthetic resins. Work on treated fabrics has advanced far enough to show that two grades of the material are sufficient to meet all ordinary requirements. Composite insulating materials have been investigated to such a point that a specification has been drafted, but questions of inflammability, machining qualities, &c., are still under investigation. In the section dealing with mica classification is complete, and a report will shortly be ready on the use of mica for commutators and condensers. Numerous researches on insulating oils are in hand, and the study of resistivity in relation to moisture content and dielectric strength has necessitated a comprehensive research. Other work being carried out covers electric control apparatus, investigations being made on the important subjects of the rupturing capacity of oil circuit-breakers, and the pressure developed in switch chambers by gaseous explosions and the rupturing of electric circuits. These latter researches are being carried out by the Home Office at Eskmeals and the National Physical Laboratory. Direct-current circuit-breakers are the subject of extensive inquiries, which so far have emphasised the lack of fundamental data on the subject. The electrical engineers of the London County Council and the London and North Western Railway are co-operating in this work. On the subject of the corrosion of condensers the Association is working with the Corrosion Committee of the Institute of Metals.

Home-Grown Sugar.

The fact that in no country in which the beet sugar industry has been introduced has it failed to be commercially successful, makes the opening of the first British beet sugar factory an occasion for much hope, in spite of the fact that operations are to begin on a falling market. There is no question at all but that beet of high sugar content can be successfully grown in this country, and the only unknown factor is if such beet can be made into sugar at such a profit as to allow an adequate return to the grower. A difficulty in the matter, in view of British labour conditions, is that sugar beet requires a considerable amount of hand-thinning and hoeing, but it forms a valuable rotation crop, and the spent beet pulp treated with the by-product molasses makes a valuable food for stock for returning to the farm. The new factory is at Kelham, near Newark-on-Trent, and that farmers in the neighbourhood can be induced to grow sugar beet is sufficiently illustrated by the fact that supplies this year are being received to the extent of 20,000 tons of beet from 425 growers. The Kelham factory has been built by Messrs. Home-Grown Sugar, Limited, of which company half the share capital has been subscribed by the Government. The whole scheme owes its initiation and development to the British Sugar Beet Growers Society, Limited, of 14, Victoria-street, Westminster, which bought the Kelham estate with advances from the Development Fund. The estate, which covers 2,834 acres, was bought by the society in 1917 and transferred to the company in 1920. Beet supplies will be drawn from the estate as well as from local growers. The area devoted to the factory covers 41½ acres. There are six ferro-concrete silos with a capacity of 5,000 tons of beet, and railway sidings to accommodate 150 trucks. There is also a ferro-concrete wharf, 181 ft. long, on the River Trent. The factory can deal with 60,000 tons of beet in a season, which covers 100 days of 24 hours working, including Sundays. The expected production is 8,000 tons of sugar, 3,000 tons of dried beet pulp, 1,800 tons of molasses and a large quantity of lime waste which is a valuable manure. During the present season only some 20,000 tons of beet will be dealt with, it being deemed inadvisable to attempt more with unskilled labour and a new factory. There is nothing experimental about the installation and the whole of the sugar plant follows standard French practice. It was supplied by the Compagnie de Fives-Lille, of Fives-Lille (Nord). The building contractors were Messrs. Walter Scott and Middleton, Limited, and the consulting engineers and architects Messrs. Hal Williams and Co. The formal opening of the factory was performed on Wednesday last by the Right Hon. Sir Arthur Griffith-Boscawen, Minister of Agriculture. We sincerely hope that the event marks the beginning of a continuously profitable British industry.

Lloyd's Register of Shipping.

In view of the unprecedented decline in shipbuilding activity which has occurred during the last year or so from causes which have frequently been referred to in our columns, it is by no means surprising that the tonnage of new vessels classed by Lloyd's Register during the year ended June 30 last was some 25 per cent. less than the corresponding figure for the previous year. From the report of the Society recently issued we learn that the new tonnage classed in the year 1920–1 amounted to 3,245,130 gross tons, as compared with 4,253,523 gross tons in 1919–20. The latter tonnage was, of course, a record figure, but it is a notable fact that it included only one vessel with a tonnage exceeding 10,000, whereas in 1920–21 ten such vessels received the Society's classification. The three largest of these were the Cameronia, 16,280 tons; the Oropesa, 14,072 tons; and the Albania, 12,768 tons. The aggregate gross tonnage of the other seven vessels amounted to 73,864. The most remarkable feature of the report, however, is the evidence it contains of the extent to which oil has superseded coal as a fuel for marine propulsion. For the first time in its history, the Society has classed more oil-fired than coal-fired tonnage in one year, the figures for the period under review being 1,867,115 tons and 1,260,465 tons respectively. If we add to the former the 101,608 tons of motor vessels classed, the total tonnage of vessels using oil as fuel becomes 1,968,723, this figure representing 61 per cent. of the total self-propelled tonnage classed in 1920–21. There is, of course, no need at this time to call attention to the advantages of oil fuel for marine purposes, but it may be interesting to quote some figures to show the development which has taken place in this particular application during the period subsequent to the war. According to the report, the aggregate tonnage on the Register Book of steamers burning oil fuel was 5,336,678 in July, 1919, 9,359,334 in July, 1920, and 12,796,635 in July of this year, and the industrial significance of these figures will be better realised when it is pointed out that the oil-fired steamers now in existence would require some 20,000,000 tons of coal per annum if arranged for burning that fuel. This quantity of coal, it may be added, represents nearly 9 per cent. of the British production for 1920. In referring to the Society's work abroad, the report mentions that the policy of establishing committees in foreign countries has been continued, committees similar to those previously formed in the United States, France and Sweden having been formed during the year in Holland and Japan. The Society's operations have been resumed in some ex-enemy countries, full staffs being now engaged in Germany and Fiume; an office has also been established in Prague for the convenience of clients in Czecho-Slovakia. A surveyor has also been stationed in Winterthur to deal with the Society's work in connection with marine Diesel engines and accessories built there or in other parts of Switzerland. The surveys and certificates of Lloyd's Register, it may be added, are now recognised by France, Holland, Norway, Sweden, Denmark, Spain, Greece, Belgium, Portugal and the British Dominions, as exempting vessels from various Government inspections, and, owing to this fact, the owners of vessels trading to, or belonging to, those countries are, of course, saved much inconvenience and delay. The retirement of Dr. James T. Milton from the position of chief engineer-surveyor to the Society, which he has held for over 30 years, is referred to in the report, and the appointment of Mr. H. Ruck-Keene as his successor is mentioned. Other changes in the staff and committee are dealt with, and of these we have already mentioned the retirement of Sir Thomas L. Devitt, Bart., from the chairmanship of the Society. Sir John H. Luscombe now occupies the chair, while Mr. J. H. Scrutton has been elected deputy chairman and treasurer in succession to Sir John Luscombe.

INDUSTRIAL NOTES.

THE result of the ballot of the branches of the Amalgamated Engineering Union, the Foundry Workers' Union, the General Workers' Federation and the Shipbuilding Federation was made known last Saturday; the members voted on the question of the withdrawal of the munitions bonus in three instalments. The figures were:—

For withdrawal	170,471
Against	147,636
Majority for withdrawal	22,835

As will be seen, the men who took the trouble to vote numbered only 318,107, out of a total of probably 2,000,000, in round figures. A natural inference to be drawn from the above result is that the men who abstained from voting—mainly, it is reported, skilled and semi-skilled men—are in favour of the withdrawal of the bonus in question, namely, the 12½ per cent. bonus on the total earnings of time workers and the 7½ per cent. bonus on those of piece workers. The country is to be congratulated on this result. Detailed figures of the voting show that whilst of the General Workers' Federation there voted 58,299 for the withdrawal and 26,837 against, the members of the Amalgamated Engineering Union voted 48,976 for and 66,682 against. The Admiralty have notified all dockyard workers that any settlement becoming operative following upon the ballot above referred to will be applied to the men employed in all the Admiralty establishments.

Mr. F. Hodges put forward last week on behalf of the Miners' Federation a scheme according to which the balance (about 3,000,000*l.*), unexpended on the 10,000,000*l.* subsidy voted by Parliament in relief of miners' wages during the temporary period of July, August and September, should be spent in relief of wages in those districts where the cut is the heaviest, and in continuing work at the collieries which otherwise will be shut down. The Government have stated in reply that they are unable to agree to this, and the balance reverts to the Treasury. The scheme propounded by the Miners' Federation would have involved financial help on the part of the Government to the extent of probably three times the unexpended balance in question; it proposed that the maximum price for industrial coal be 30*s.* per ton, delivered, the Government making up the difference to the coalowners and to the railway companies out of Exchequer grants, the scheme lasting probably for a period of six months. Its object was "to restart the industries of the country and create a demand for coal." It meant subsidising the miners' wages for a longer period, at the cost of the taxpayers throughout the country, and was viewed with disfavour by every industry from the moment Mr. Hodges proposed it. Many industries will require coal at a much lower price than 30*s.* per ton to make a fresh start.

Lieutenant-Colonel D. Watts-Morgan, Labour M.P. for Rhondda East, suggested to the Government a scheme involving a loan by Government to the coal trade of 1,000,000*l.*, the proceeds of which loan would be applied, by payments to the coalowners up to 10*s.* per ton, to lowering the cost of coal production, making it possible, therefore, for coal to be sold at a lower price than the present one, this having for effect to stimulate the revival of trade generally and to keep a larger number of miners at work. The above sum of 1,000,000*l.*, which would be distributed by the National Coal Board, would be paid back at the end of twelve months. The Government are unable to sanction this scheme any more than the one put forward by Mr. Hodges; its effect would be to afford an artificial stimulus to the coal-mining industry, and the coal miner out of employment cannot be treated differently from all other unemployed, for all of whom Government has made the proposals briefly referred to in our last issue. Moreover, a total sum of 1,000,000*l.* would not suffice to overcome the present difficulties.

An agreement has been arrived at between the railway companies and the National Union of Railwaymen for raising the adult age of railway servants from 18 to 20. The rates of wages are as follow: For youths of 15 or under, 16*s.*; on reaching 16 years, 20*s.*; 17 years, 25*s.*; 18 years, 30*s.*; 19 years, 35*s.*; the adult rate being paid at 20 years of age. The lower age limit was established during the war, and was not liked either by the companies or by older men, the latter contending that a lad of 18 was not able to carry the responsibility which they had to bear for a like wage.

A well-attended meeting of the Joint Industrial Councils representing the British Electrical Industry was held in London last Friday, when the workers' representatives expressed their readiness to co-operate in any schemes likely to lead to a revival in the industry; they promised to encourage the workers to put forward their best endeavours to that end.

At a recent conference of representatives of the Shipbuilding Employers' Federation and the Shipbuilding Trade Unions, a proposal by the employers was considered to the effect that the 47-hour week should operate all the year round for outside workers in the districts of Birkenhead (joiners) and Hull (boilermakers and shipwrights) who have been working on the 44-hour or 44½-hour week during certain winter months. It was reported at the close of the meeting that it had been mutually agreed to refer the point to the districts for further consideration, with a view to an amicable settlement.

According to *Swedish Export*, the efforts to adapt the costs of production in Swedish industry to the changed economic situation have led to a substantial reduction of wages in most trades during the present year. On the average the wages for Swedish industrial workers would seem to have been reduced by 17 per cent. This means that the lowering of the wage level has gone just about as far as the lowering of the cost of living, which has sunk 16 per cent. from its summit level on October 1, 1920.

Dealing with economy in the Danish Public Service, the *Danish Foreign Office Journal* says that the special committee representative of the Rigsdag, the administrative offices and the organisations of public servants, which was appointed in February last to consider the possibility of effecting economies in the administration of the various public services, has now presented a report as to the ordinary service regulations and the questions of weekly holiday and pay for overtime. On the main points the committee is fairly unanimous. In regard to the telegraph service the committee, with only one dissentient, recommends that the present 7-hour day should be increased to 8, 9 or 10 hours, the exact number of hours in each case depending on the degree of effective work performed in a given time. The committee recommends that free time should be given in lieu of payment for overtime. In the case of sickness the committee recommends that the rate of pay should be reduced after sick pay has been granted for a total of 180 days, even when that period is spread over several years. The proposed alterations as to service time are not to apply to higher-grade servants.

RESULT OF TENDERS FOR IRON BRIDGE, BELGIUM.—The result of the public adjudication of tenders, invited by the municipal authorities of Antwerp for the supply and construction of a new pivoting bridge over the railway lines crossing the canal between "le bassin Asie" and "le bassin aux Bois," has been published in *l'Exportateur Belge* as follows: S.A. des Forges de Bellecourt Manage, 360,911 francs; S.A. de Construction et des Ateliers de Willebroeck, Bruxelles, 385,000 francs; Soc. Usines Ragheno, Malines, 395,000 francs; Soc. A. des Ateliers de Construction de Joseph Paris, Marchienne-au-Pont, 410,400 francs; Soc. An. l'Hydraulique, Bruxelles, 429,731 francs; Felix Frankowski, Bruxelles, 437,800 francs; J. Bolsee, Bruxelles, 439,400 francs; N.V.F. Kloes en Zonen's Werkplaatsen, Kinderdijk (Holland), 123,500 fl.

METAL COATINGS FOR IRON.—A series of tests on the durability of metallic coatings, applied to iron to prevent rusting, were conducted by Dr. W. Lange, of Berlin, on behalf of the War Office during the war, and the results of the tests were published in the April and June issues of the *Zeitschrift für Metallkunde*. The protective metals tested were zinc, lead, tin, aluminium, and the tests were made on foils or wires, in water (distilled or tap water), in diluted solutions of common salt or sea water, and in the open air, sometimes saturated with moisture and carbon dioxide. In the case of zinc various electrolytic baths were used, and also the nigrosin treatment of Langbein-Pfanhauser, in which a film of black nickel is finally deposited by electrolysis on the coating which is subsequently greased with vaseline; the good results obtained may partly be due to the vaseline. Electrolytic zinc coatings failed in many cases because they were of insufficient thickness. Dipping into fused zinc avoids this trouble; sherardising answered nearly as well as this last process, although the coatings were not of uniform thickness; spraying after Schoop was also fairly satisfactory, except in distilled water—which is far more destructive to all zinc coatings than tap water—and in salt solution. Of the electrolytic lead baths those of Betts (hydro silico-fluoric acid) and of Schlötter (phenolsulphonic acid) answered best; distilled water again proved more destructive than tap water and salt solution. When lead is to be sprayed on, a film of zinc or tin should first be applied to the iron by spraying in order to secure adhesion. In the case of tin, alkaline baths, a solution of the double tin ammonium chloride and the Schlötter acid were tried; the last-mentioned bath answered best. A steel tube dipped into molten tin, rusted in three weeks when heated by steam during the day and kept cold at night. Very good results were obtained with aluminium-spraying. Some new secret processes did not pass the tests at all satisfactorily.

STRESSES IN SHIPS' PLATING DUE TO FLUID PRESSURE.

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of Friday last, in the second paragraph of my letter on the above subject, printed on page 612, I notice the word "quantitative" before the word "diagram." The first word is, unfortunately, a printer's error, as the word quantitative should have been qualitative. I should be much obliged if you would correct this in your next issue.

Yours faithfully,

T. B. ABELL.

The University of Liverpool, School of Naval Architecture, November 1, 1921.

SPECIFICATION FOR CONDENSER TUBES AND GLANDS.—Report No. 145—1921, recently issued by the British Engineering Standards Association, gives the British standard specification for condenser tubes and screwed glands for condensers used for marine purposes. The specification, which covers the quality of the material, dimensions, weights and tests, both for the condenser tubes and for the tubes from which the screwed glands are made, relates to the two sizes most commonly employed in marine practice, viz., ⅝ in. and ¾ in. external diameters. Dimensioned drawings of screwed glands of both sizes are reproduced, and we notice that the outer ends of the glands are chamfered to facilitate the entrance and exit of the circulating water. The report is published by Messrs. Crosby, Lockwood and Son, 7, Stationers' Hall Court, London, E.C. 4, and can be obtained from any bookseller, or direct from the offices of the association at 28, Victoria-street, London, S.W. 1. Its price is 1*s.* net, or 1*s.* 2*d.* post free.

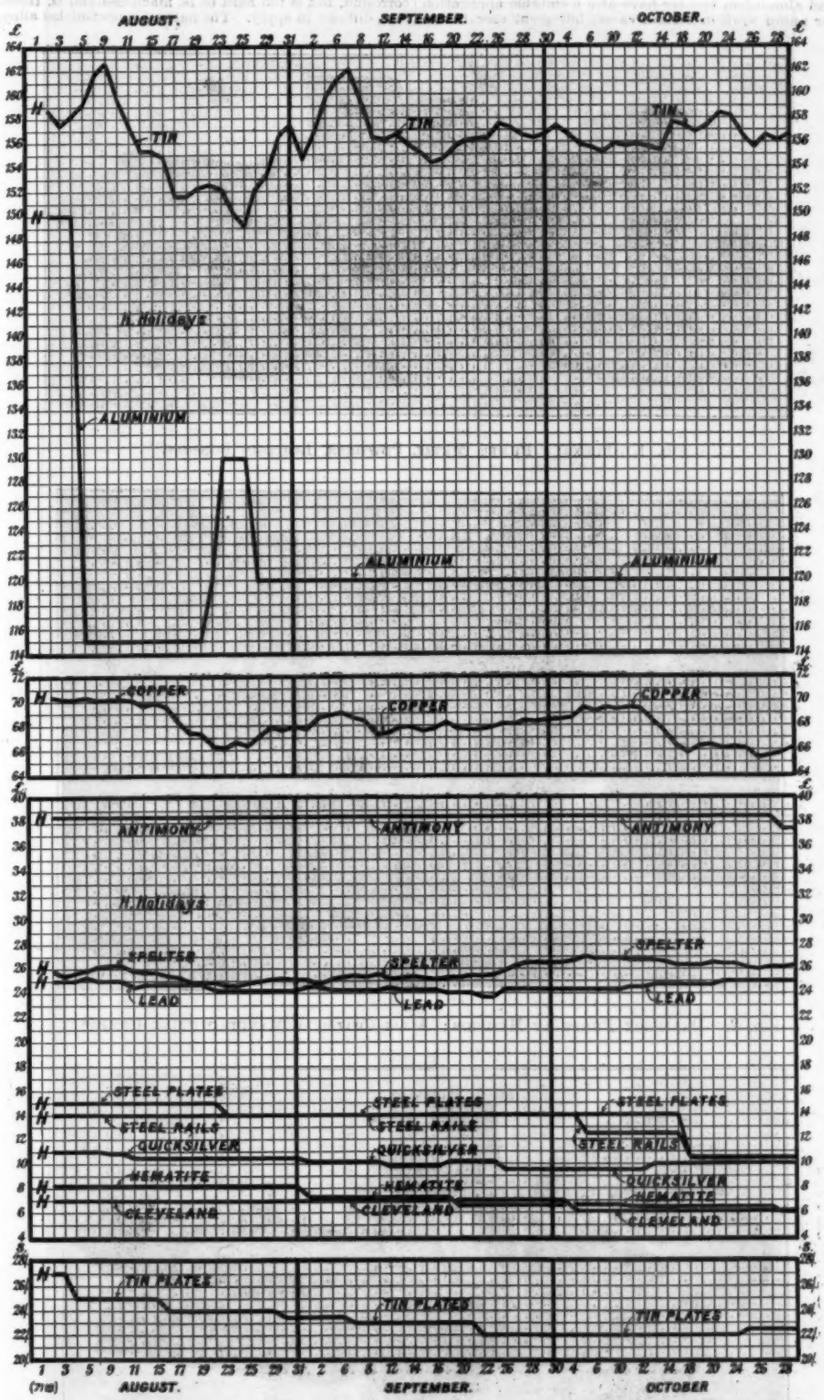
TESTING WEARING QUALITY OF SHOVELS.—We read in *Engineering News Record*, New York, that tests upon various alloyed steels, to determine the best one to use for the manufacture of shovels, have been made recently by the Wood Shovel and Tool Company, Piqua, Ohio. The tests determine not only the wear on the edge, but also that on the surface of the blade, the strength of the weld, toughness of the steel, and the durability of the straps. The testing machine had a rotating axle with four arms in which the shovels were fastened. It was driven by a 3-h.p. motor, the speed being reduced to 14 revolutions. The shovels were forced through over 3 ft. of red granite rock. Over 125,000 revolutions through the granite (a distance of over 75 miles) were made by some of the steel shovels without the blades breaking or the straps pulling loose. The test showed that one shovel would have handled 3,400 tons. Our contemporary gives no further data concerning the steel and the design of the shovels tested.

SOUTH AFRICAN COAL.—Our contemporary, *The South African Mining and Engineering Journal*, of Johannesburg, South Africa, recently published a second special number devoted to South African coal. This issue is full of interesting information and gives an historical review of the industry in question, with an account of its present status, and a discussion of the future outlook. The first attempt at anything of this kind was made by the same journal nearly two years ago. The industry has made enormous strides, and the two recent years have seen great activity in acquiring coal properties, and the development in the near future is sure to be considerable. The issue before us reviews in an interesting manner many of the important mining concerns, the work of development and exploration, and the railway and port facilities for disposing of the product. The issue, we understand, may be obtained from Messrs. Argus South African Newspapers, Limited, 82 to 85, Fleet-street, E.C. 4, the price being 5*s.*

ELECTRICITY IN COAL MINES.—A conference was recently held between the Switch-gear Section of the B.E.A.M.A. and Mr. J. A. B. Horsley, H.M. Electrical Inspector of Mines, in regard to the rules governing the construction and use of switchboards in mines, Dr. Garrard, chairman of the Switch Gear Technical Committee, being in the chair. As some of the matters for discussion also had their counterpart in factory switchboards, H.M. Electrical Inspector of Factories, Mr. G. Scott Ram, was also invited to attend. After Mr. Ram had explained the bearing of the Factory Regulations on the points in question, Mr. Horsley dealt with the requirements of the Mines Rules and called attention to the information contained in "Mines and Quarries Form No. 11 (April, 1921)," which contains the Electricity Regulations and the revised official memorandum thereon. After full discussion it was agreed to place on record the following views: (i) *The Isolation of Circuit Breakers for Cleaning or Repairs.*—In colliery surface switchboards, when a switchboard circuit comprising air break circuit breakers or contactors cannot be shut down regularly, say, once a week, exclusive of Sundays, to permit of cleaning and adjustment being carried out with safety, means must be provided for isolating such circuit breakers or contactors. (ii) *Screening.*—In view of the foregoing rule provision for fixed or movable partitions may or may not be necessary, depending upon the nature and design of the switchboard. (iii) *Insulating Barriers.*—When a switchboard has open type bus-bars arranged in the horizontal plane, insulating barriers must be fixed between them, projecting at least two inches above the upper surface of the bus-bars. (iv) *Shrouded Surface Contacts.*—When a surface switchboard contains cut-outs having surface contacts fixed on the front, and the distance between opposite poles is less than 6 in., such contacts must either be shrouded or protected by fillets provided between the poles.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for fine "foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. Middlesbrough prices are plotted for steel plates and rails, and also for hematite and Cleveland pig-iron. The prices given, in the case of steel plates are for ship, bridge and tank qualities, and those for steel rails are for heavy sections. The pig-iron prices are for the East Coast hematite and Cleveland iron, both of No. 1 quality and for home consumption. The price of tin-plates is per box of I.C. cokes f.o.b. at Welsh ports, but in all other cases the prices are per ton. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each.

THE MAGNESIUM ALLOY "ELECTRON."*

By S. BECKINSALE, B.Sc., A.I.C., Member.†

SEVERAL samples, of German origin, of the magnesium alloy known as "electron" have recently been examined, and the following brief account of its properties may serve to amplify information lately published about high magnesium alloys. The specimens were in the form of cylindrical rod 0·3 in. in diameter.

Chemical Analysis.

	A.	B.	C.
Copper per cent. ...	0·20	0·42	0·62
Zinc per cent.	4·62	4·24	4·37
Magnesium per cent (by difference)	95·18	95·34	95·01
Tin, manganese ...	nil	nil	nil
Lead, iron, aluminium	trace	trace	trace

Specific Gravity.

A.	B.	C.
1·78	1·79	1·79

Brinell Hardness Tests (1 mm. ball; 10 kg. load).

	A.	B.	C.
Exterior surface	51	51	63
Transverse section ...	50	48	59

Tensile Tests. Diameter of test-piece, 0·180 in. Elongation measured on 0·64 in. ($= 4\sqrt{\text{area}}$).

	A.	B.	C.
Yield-point (by dividers), tons per square inch...	12·0	7·6	12·0
Maximum load, tons per square inch	16·1	18·0	18·4
Elongation per cent. ...	19·0	19·0	13·0
Specific tenacity: $\left\{\frac{\text{Maximum load in tons per sq. in.}}{\text{Weight of 1cub. in. in lbs.}}\right\}$	250·0	278·0	284·0

Compression Tests on Cylinders, 0·31 In. Diameter; 0·31 In. Long.

	A.	B.	C.
Yield-point, tons per square inch (compression, 0·5 per cent. with load on)...	3·0	6·0	8·4
Permanent reduction in length at—			
Loads of 10 tons per square inch, per cent.	3·9	2·0	1·0
Loads of 20 tons per square inch, per cent.	10·1	9·1	7·0
Crushing load, tons per square inch. Fracture occurred by shearing ...	23·0	22·3	23·9

Microscopical Examination.—All samples showed equiaxial polyhedral crystals of a single solid solution. One end of sample C, which had been headed, showed distortion of the grains; these were elongated in the direction at right angles to the axis of the rod.

The specimens were polished on fine emery-paper impregnated with paraffin wax followed by selvyt, to which a little metal polish had been applied. The specimen, to which a trace of polish adhered, was then transferred to clean selvyt.

A satisfactory etching agent was a solution of 1 per cent. hydrochloric acid and 0·5 per cent. nitric acid in alcohol.

Machining Properties of the alloys were very satisfactory, and a good finish was produced by shaping or turning. It may be remarked that on account of the danger of fire the manufacturers issued very strict regulations to prevent the accumulation of turnings beyond a certain amount in the factories where these alloys were machined.

Summary and Conclusions.—The samples of "electron" examined contained about 95 per cent. of magnesium, 4·5 per cent. of zinc, and 0·5 per cent. of copper. They were in the form of rod, probably extruded at a raised temperature; one sample showed evidence of having been subjected to cold heading. The alloys machined well, and compared very favourably with aluminium alloys in tensile properties (allowance being made for the much lower specific gravity), but they were not so ductile in compression.

THE LATE PROFESSOR F. E. ARMSTRONG.—We regret to have to record the death at the early age of 42, of Professor Francis Edwin Armstrong, M.Sc., Professor of Mining at Sheffield University. Mr. Armstrong was the son of the Rev. R. A. Armstrong, of Liverpool, and was educated at Giggleswick School and University College, Liverpool. He was articled to Mr. Arnold Lupton at Tinsley Park Colliery, Sheffield, subsequently becoming assistant to Mr. J. H. W. Laverick of the Riddings Collieries, Derbyshire. He afterwards transferred to Warwickshire, but in 1906 was sent out to mines in Mexico by Sir Ernest Cassel. He afterwards reported on coal mines in British Columbia. In 1910 he was appointed engineer to the Askern Coal and Iron Company, Doncaster, and in 1913 took up the professorship at Sheffield. He was head of the Wages Section of the Coal Mines Department of the Board of Trade in 1917 and 1918, and a member of the Home Office Committee on Miners' Safety Lamps in 1919.

* Paper read before the meeting of the Institute of Metals, at Birmingham, September 22, 1921.

† Communication from the Research Department, Woolwich.

THE CENTRIFUGAL PUMP.*

By S. F. Barclay, D.Sc., M.Inst.C.E.

The fundamental principle of the centrifugal pump is to impart velocity to the liquid being pumped and then convert a part of the energy of movement into the potential energy of pressure. It is probable that the principle was known to the early civilised peoples, but the first definite reference that can be traced is in the fourteenth century records of the French Academy. Probably the first practical pump was made in the United States in 1818. In this country the regular manufacture of centrifugal pumps was started by John Gwynne in 1849. One of the most important advances in the history of the centrifugal pump was made in 1875, when Osborne Reynolds patented the system of stationary guide vanes for improving the conversion of the kinetic energy of the water leaving the pump impeller into pressure head. The first pump of this kind was made by Messrs. Mather and Platt, Limited, of the Salford Iron Works, Manchester, in 1887, and this pump is still in use in the engineering laboratories of the Manchester University.

Centrifugal pumps are divided broadly into two classes—volute pumps and turbine pumps. With the former type, the liquid after leaving the impeller passes into a spiral casing so proportioned that the liquid flowing round the circumference has a uniform velocity at all points. With the turbine pump the liquid after leaving the impeller passes through a series of guide vanes (often called diffusers) of the kind invented by Osborne Reynolds, with the object of reducing the velocity of the liquid and increasing the pressure. The function of the volute or of the guide vanes, according to the type employed, is clearly to provide a form of Venturi tube in which, with as little loss as possible, some of the velocity energy of the liquid as it leaves the impeller is converted into pressure energy before the liquid enters the pump discharge. The volute pump is clearly the simpler and cheaper type, and is to be preferred for low and medium lifts with which the sacrifice of efficiency is small and the gain in other respects is important; and, in particular, when the liquid to be pumped contains large solids or has serious corrosive action. For high and extra-high pressures, however, a much greater proportion of the kinetic energy of the liquid has to be converted into pressure energy, and the gain from using the guide vanes in the better pressure conversion, and in the greater efficiency of conversion, fully justifies the increased complication. Both types of pump have their inherent desirable and less desirable features, and the best type to employ for a given purpose calls for well-experienced judgment.

The volute pump and the turbine pump each has its fundamental characteristics, but it is in the hands of the designer to vary the characteristics considerably; thus, a pump can be designed so that as the discharge increases the pressure head increases, remains constant or falls. The conditions under which a pump is required to work should, therefore, be carefully investigated, and the pump design be varied accordingly. The relationship between the volume of liquid flowing and the power required to drive the pump is called the regulation and is an important characteristic. As the volume of liquid is reduced below the normal, the driving power decreases, and as the volume is increased above the normal, the driving power increases. It is almost possible, for instance, by the accidental breakage of the pipe line, for the pump discharge to be enormously increased, and it is desirable that the pump should be so designed that as the volume increases above the normal the pressure falls away rapidly whilst the efficieny is well-maintanied, and so serious overloading of the driving motor is avoided. With low lift and medium lift pumps there is little difficulty in proportioning the moving and standing parts so that the maximum power absorbed by the pump cannot exceed the normal full load by more than from 10 per cent. to 15 per cent. With turbine pumps it is difficult to give good self-regulation without adversely influencing the other characteristics. The centrifugal pump should be designed so that it has its maximum efficiency at the normal rated output, and the curve should be as flat as possible. With a correctly-designed pump it should be possible to vary the discharge by as much as 30 per cent. above or below the normal without lowering the efficiency more than about 4 per cent. With medium lift pumps it is possible to realise efficiencies as high as 80 per cent., or even higher, but for high pressures the efficiency is somewhat less.

The Mechanical Design.—The centrifugal pump has claimed in the course of its development the attention of many of the world's greatest mathematicians and engineers, and the theory of design is substantially complete. There is still more scope for improvement, but such improvement must lie almost wholly in the capacity of the metallurgist to produce improved materials of construction, and in the capacity of the engineer to produce greater excellence of mechanical design. In common with most engineering products, the evolution of the centrifugal pump has been delayed by attaching undue importance to low cost of production instead of aiming at giving the highest ratio of the value of the service rendered to the cost. The corrosive nature of the water being pumped is one of the greatest troubles with which the pump designer has to contend, and great care has to be exercised in the selection of the materials employed. If cast-iron is used, it should contain as much combined carbon as possible consistent with being machinable, and should have a fairly low phosphorus content. Phosphor-bronze is a good material for resisting mineral acids, provided that the concentration is low; it is important, however, that the zinc and lead impurities should be kept down to a low value. Nickel and aluminium bronzes have also a suitable application for pump work in certain cases, but great care has to be exercised to see that the raw materials employed are reasonably free from impurities. Tungsten-nickel alloys have good anti-corrosive properties even when the acid concentration is considerable, but they have the disadvantage of being expensive. Tungsten-nickel-copper alloys are less expensive and have a useful application in some cases, but great care must be exercised in their manufacture or they will be found to lack desirable mechanical qualities. High silicon cast-iron has very good acid-resisting properties, but has the important drawback that it cannot be machined. If considerable free graphite is introduced into the iron it can be rendered machineable, but then there is difficulty in securing sound castings. High-manganese steel is excellent for resisting abrasion and is good for resisting corrosion, but is too hard to be machined and is, therefore, difficult to apply. The natural copper-nickel alloy, Monel metal, can be employed successfully for shafts and for other parts in certain cases. Also the high-chromium steel known as "stainless" steel may have a useful application in special circumstances, but it should be remembered that the stainless and rustless qualities of this alloy are dependent mainly on the surface having a good polish. Nickel steels, containing upwards of 5 per cent. of nickel, are more resistant to corrosion than plain carbon steels, and can be employed with advantage in certain cases. Manganese bronze has excellent

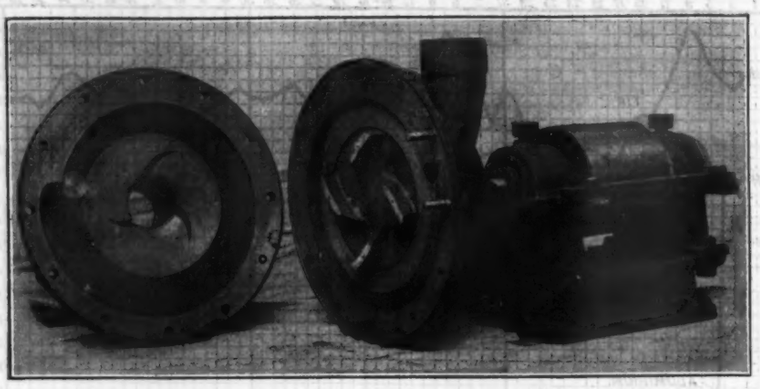


Fig. 1. Flexala Pump; Metal Powders, Limited, London.

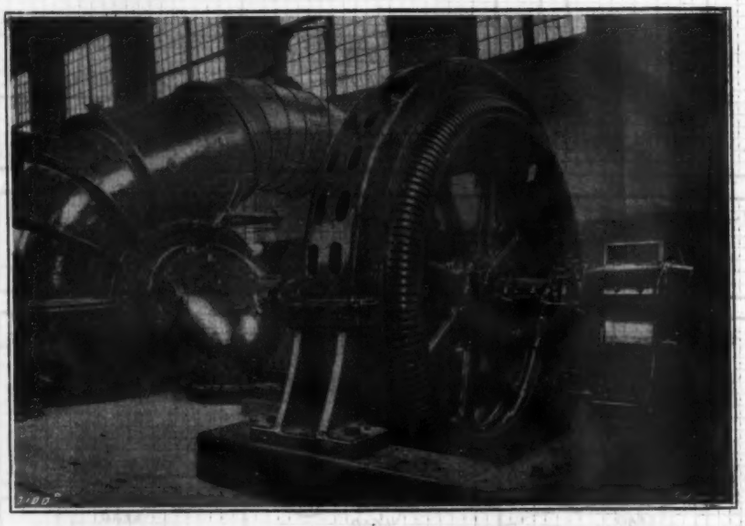


Fig. 2. Drainage Pumps at Memphis; Allis Chalmers Manufacturing Company.

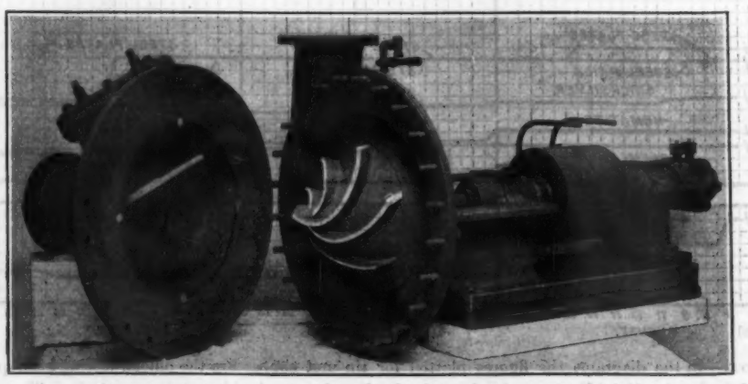


Fig. 3. Stereophagus Pump; Pulsometer Engineering Company, Limited, Reading.

* Abstract of paper read before Section G of the British Association at Edinburgh, on September 14, 1921.

CENTRIFUGAL PUMPS.

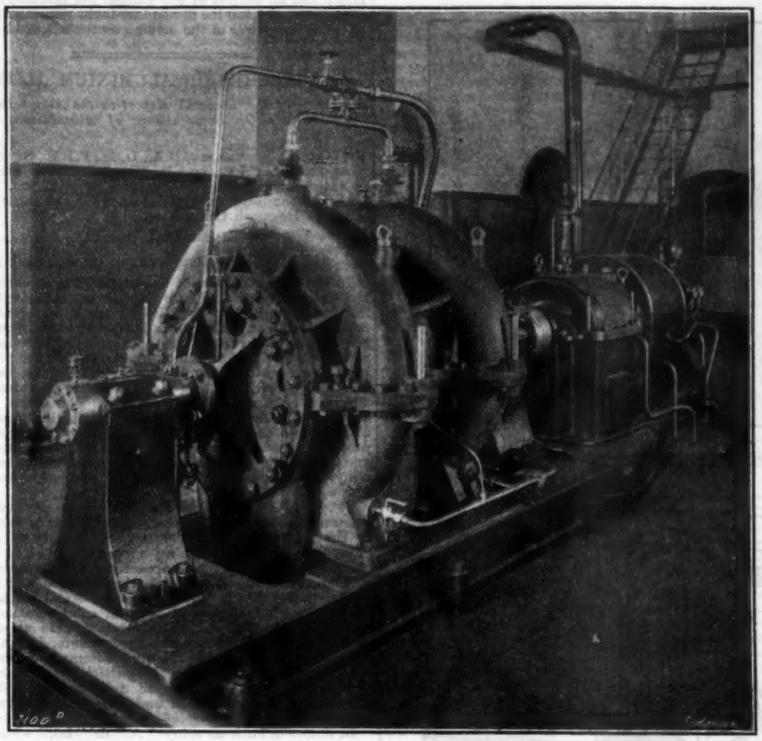


FIG. 4. SINGLE-STAGE TWIN-IMPELLER PUMP; MESSRS. GWYNNES, LIMITED, LONDON.

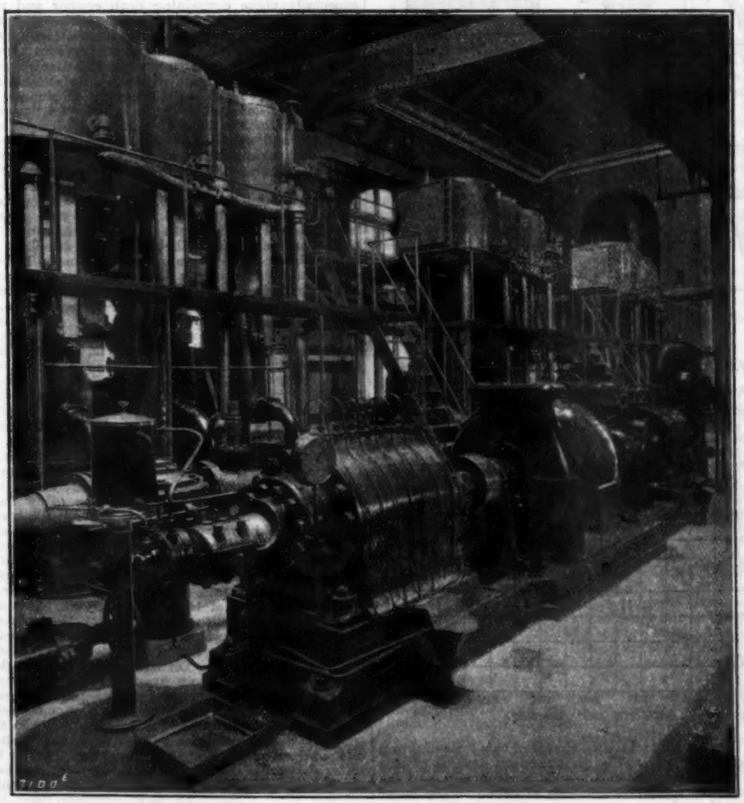


FIG. 5. HIGH-PRESSURE MULTI-STAGE TURBINE PUMP; MATHER AND PLATT, LTD., MANCHESTER.

mechanical properties, but has to be used with care if the water being pumped contains mineral acids.

Next to corrosion, the greatest cause of trouble with centrifugal pumps is the running and standing parts coming into contact and seizing. In the multi-stage pumps the bearing span in many cases is so considerable that if there were no intermediate support the critical speed would be below, or in the neighbourhood of, the running speed. The neck rings and bushes are given fine clearances and serve as shaft supports in limiting whipping and in damping vibration. The only lubrication is from the liquid being pumped, and it is obvious that such supports are not entirely satisfactory as bearings. There are great numbers of pumps arranged in this way in satisfactory operation, and the percentage that give trouble through seizing is very small. Nevertheless, it would be a sounder construction to provide, in all cases, rigid shafts with the first critical speed above the running speed and with adequate clearances between the running and standing parts to preclude the possibility of their coming into contact. The selection of the shaft material is an important item; a good quality of plain carbon steel with a carbon content of from 0·3 per cent. to 0·35 per cent. is probably the best for pumps for normal waters. The steel should preferably be oil-hardened and tempered, but if the stresses are low it may be normalised only. The shaft should be rough turned before heat-treated in order to ensure the elimination of initial stress and so safeguard against any possibility of becoming untrue after being put into service. If the stresses are high, a nickel or nickel-chrome steel may be used with advantage, but in all cases, if an alloy steel is employed, it should be oil treated in order to bring out the best qualities of the material.

An important item in designing centrifugal pumps is in making provision for dealing with end thrust. With the double entry type of impeller, as is commonly employed for low and medium lifts, the rotor is hydraulically balanced and a light locating thrust bearing is all that is required. With high lift, multi-stage pumps, although it is possible to provide double-entry impellers, such a design is now little used on account of the difficulty with the tortuous water passages involved, and arrangements have to be made for dealing with an end-thrust amounting to as much as several tons. A very satisfactory type of automatic balance disc was evolved by Messrs. Mather and Platt in 1906, and is now in general use. The disc is subjected to the pump pressure at one side to balance the rotor thrust, and it floated in an intermediate position between two seatings. If the disc tends to move from its central floating position, there is a reduced leakage between the disc and the seating to which it has moved, and an increased leakage between the disc and the seating from which it has moved, and the pressure on the disc is thereby automatically changed, and it is restored to its normal position. The Michell thrust bearing is capable of dealing with very heavy thrusts, and is now being applied to a certain extent to turbine pumps.

The Application of Centrifugal Pumps.—Centrifugal pumps are now being employed for pumping water for every conceivable purpose, and also for water containing quantities of abrasive and other solids; in addition, they are being used for raising semi-liquids, crude oils, coal tar, acid liquors, &c. The popularity of the centrifugal pump is due to the low initial cost, small space required, adaptability to all possible conditions, simplicity of construction that calls for little attention when running, and the suitability for direct coupling to high-speed steam turbines and electric motors.

One of the most recent and difficult applications of the centrifugal pump is to the raising of strong acid liquors. The Lennox Foundry Company, of London, have developed a special pump for the purpose, made of an acid-resisting alloy they call "tantcopper." Another type of pump suitable for dealing with acid liquors and many other kinds of chemicals is made by Messrs. Metal Powders, Limited, and is known as the "Flexals" pump. Fig. 1 shows a photograph of a small pump with the end cover removed. The impeller is rubber-lined, with flexible vanes formed out of a specially-selected pliant quality of rubber. When used for corrosive liquors, the whole of the impeller and the pump casing are also covered with rubber. This type of pump is also well adapted to pumping liquids containing a large quantity of gritty matter. A well-known property of the pliant type of rubber used in these pumps is that exposure to a high-velocity sand blast, even for a lengthy period, does not appreciably erode the surface, and the makers claim that this pump is more resistant to wear when pumping erosive sands than are pumps lined with manganese steel or chilled white iron. The function of the spiral grooves cut in the face of the front cover is to provide a self-clearing action in the event of obstructive objects being drawn into the pump.

The Wilfley Company, Limited, of London, make a novel type of pump for such severe work as sand and gravel dredging. In this the impeller hub is extended at the suction side and runs in a packed gland. In this simple manner leakage from the pressure to the suction side is prevented, and the impeller clearances can be made as large as is required. With a pump of this type solids up to 1 in. diameter can be dealt with safely.*

An important application of the modern centrifugal pump is for drainage work. Fig. 2 shows one of four large drainage pumps built by Messrs. the Allis-Chalmers Manufacturing Company, of America, for the City of Memphis. These pumps are of the double-suction type and are the largest direct-coupled, motor-driven centrifugal pumps in America. Each unit has a capacity of

* An illustrated description of the Wilfley pump was given on page 116, vol. cxi, ENGINEERING.—Ed.E

135,000 gallons per minute against a head of 15 ft., running at 120 r.p.m.

For sewage work special precautions have to be taken in designing the pump impeller on account of the possibility of the large solids that may be contained in the water. Fig. 3 shows the type of impeller made by Messrs. The Pulsometer Engineering Company, Limited, which is stated to have an excellent self-clearing action.

An important application of the centrifugal pump is in connection with dry docks. With pumps for such a purpose special arrangements have to be made to deal with the varying head. Messrs. Drysdale and Co., Limited, employ an arrangement whereby the load on the motor is kept constant over the whole range of head from "Dock full" to "Dock empty."

When a centrifugal pump is driven by a steam turbine there is the difficulty that the best speed for the turbine is usually higher than the pump speed, the latter having to be regulated to suit the height of lift. For the turbine to operate at an economical speed it is therefore desirable to introduce gearing between it and the pump, and Fig. 4 is an interesting example of this arrangement. The pump, made by Messrs. Gwynnes, Limited, has a single-stage twin impeller, 24 in. in diameter, for an output of 10,000,000 gallons in 24 hours, and is driven through gearing by a 700 b.h.p. turbine made by Messrs. Parsons. It is also a growing practice to employ reduction gearing with motor-driven pumps, so that the best pump speed and the most economical motor speed can be selected.

Fig. 5 shows a typical high pressure, multi-stage turbine pump as manufactured by Messrs. Mather and Platt, Limited, of Manchester. The photograph is interesting in showing the comparison between the turbine pump and the piston pump for similar duties. Fig. 6 is a photograph showing the details of construction of this type of pump. In Fig. 7 is shown a sectional view of a Mather and Platt medium lift pump; stationary guide vanes are not provided and the water, after leaving the impeller, passes into an involute casing. This type of pump is self-regulating, so that even in the event of a completely free discharge the power absorbed by the driving motor rises only a little above the normal full load. Typical characteristic curves of this type of pump are shown in Fig. 8. The best modern designs of this type of pump have the casing split horizontally, and the inlet and outlet pipe connections attached to the lower casing so that the pump can be inspected and the rotor removed with a minimum of trouble. A particularly important application of the high-pressure turbine pump is for hydraulic installations. This type of pump has the great advantage that it delivers water in an even stream, and no vibration or shock is communicated to the pipe system. In the largest, single unit, hydraulic pressure pumping plant that has so far been made, the pump has an output of 800 gallons per minute, against a pressure of 1,500 lb. per square inch, running at 1,450 r.p.m.; the power of the driving motor is 1,400 b.h.p.

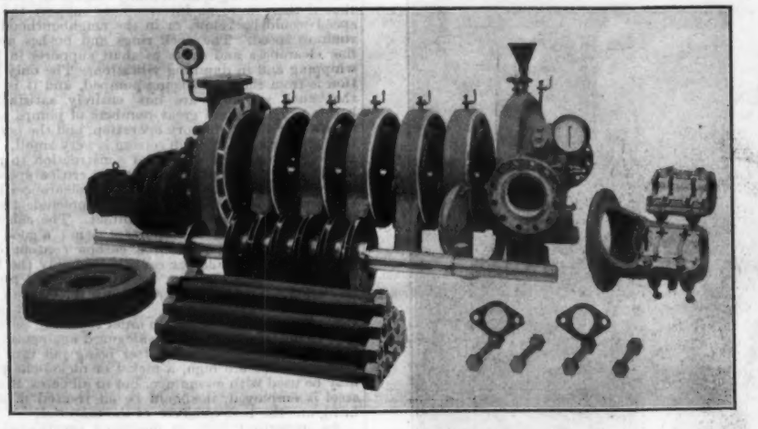


FIG. 6 DETAILS OF MULTI-STAGE TURBINE PUMP.

Fig. 7.

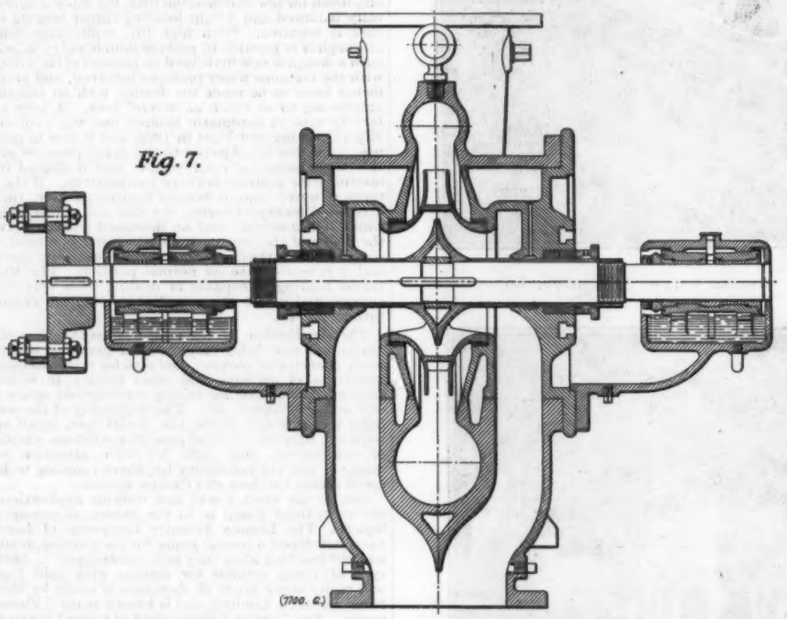
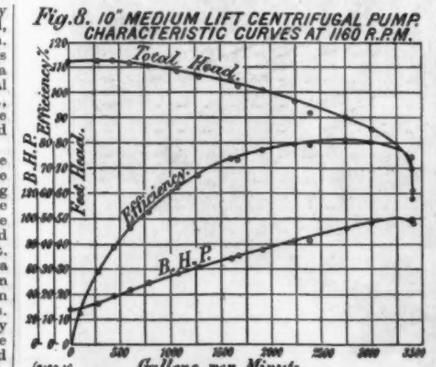


FIG. 7. MEDIUM-LIFT PUMP; MATHER AND PLATT, LIMITED, MANCHESTER.

Fig. 8. 10" MEDIUM LIFT CENTRIFUGAL PUMP. CHARACTERISTIC CURVES AT 1160 R.P.M.



RESEARCHES ON ALUMINIUM ALLOYS.

*Summary of the Eleventh Report to the Alloys Research Committee: On Some Alloys of Aluminium. (Light Alloys.)**

By WALTER ROSENHAIN, B.A., D.Sc., F.R.S., SYDNEY L. ARCHBUTT, F.I.C., and D. HANSON, D.Sc., from the National Physical Laboratory, Teddington, where the Research was carried out under the auspices of the Alloys Research Committee.

(*Concluded from page* 615.)

SECTION IV; PERMANENCE OF THE ALLOYS.

In the past some doubt has at times been thrown on the reliability of aluminium alloys. Although this has now been largely dispelled by the wide use of these materials in war, the authors decided to examine a number of these alloys from time to time, in order to ascertain what alterations, if any, took place either in the physical properties or in their dimensions. In some cases it has been possible to test materials after an interval of 10 years from the time of casting. The whole of the evidence obtained shows that, within the limits of time covered by the present research, any alterations in properties are accompanied by increases in both strength and hardness. In regard to shape and dimensions, the alloys examined are all adequately stable for practical purposes.

IV. (*a*). *Ageing.*—The changes which are found in these alloys appear to be somewhat similar in character to the age-hardening which occurs, usually in a few days, in alloys containing magnesium, after being quenched from suitable temperatures. The nature and mechanism of this change has been studied and is discussed in Section V. of the report. Age-hardening is caused by gradual separation from solid solution of a dissolved substance which is more soluble at a high temperature than at normal temperature, in an alloy which has been cooled too rapidly for immediate complete separation to take place. The particles which are precipitated from solution are in a finely-dispersed condition, and cannot be seen under the highest available magnifications.

In material such as alloy "A" or "L5," which has been rapidly cooled, it is possible that the compound $CuAl_2$ might separate in this manner and cause the slight alterations in properties that have been found.

Cast Alloys.—Results of ageing tests on cast alloys, especially those containing both copper and zinc, are given in Table XLVII. of the Main Report. The alloy "L5," in the form of chill cast bars, 1 in. in diameter, increases in strength by about 30 per cent. during the first 10 months after casting, while a similar improvement in strength is also found in the harder alloy containing 3 per cent. of copper and 15 per cent. of zinc.

Wrought Alloys.—The ageing of alloy "A," particularly in the form of hot-rolled rod and sheet, has been closely studied, and samples from the same cast have been tested at various times over a period of 5 years. The increase of strength after ageing is most marked in thin sheet, and samples which had a strength of 27 to 29 tons per sq. in. immediately after rolling possess a tensile strength of over 32 tons per sq. in. five years later. The increase in the yield stress is still more marked, while the reduction in the ductility is small.

Circular rod and rectangular bar, 1 in. to 1⅛ in. thick, also became appreciably harder during the same period. The tensile strength in these cases rose from about 26 tons per sq. in. to about 27½ tons per sq. in., with a correspondingly small reduction in the elongation. The tests on this alloy show that ageing has by no means ceased one year after casting. It seems probable, however, that after five years it is so slow that further changes are of little practical importance. In the case of alloys "E," "F," "G" and "Y" the phenomenon has not been studied over such a long period. In view of the fact that these alloys are quenched and age-hardened in order to develop their characteristic properties, it does not appear likely that the increase in hardness due to prolonged ageing will be very appreciable. Some tests on "Duralumin," however, show that slight changes take place for some years after the alloy has been quenched. A sample tested in October, 1911, was found to have a yield stress of about 17 tons, a tensile strength of about 27 tons per sq. in., and an elongation of about 18 per cent. on 3 in.; another sample from the same piece of metal, tested in January, 1921, had a yield-stress of 20·5 tons, an ultimate stress of about 28 tons per sq. in., and an elongation of 15 per cent. While these changes in properties are quite appreciable, they do not suggest any serious deterioration of the alloy. In fact, from some points of view, the aged material is better than that freshly made. On the other hand, they do indicate internal changes over a period of many years after manufacture, and it has yet to be ascertained whether these changes come to an end or continue slowly in the same direction as that indicated by the tests or whether, as is quite possible, the direction of change is ultimately reversed and the alloys then tend to become softer instead of harder. The changes appear to be so slow that, except for structures in which permanence

* Read before the Institution of Mechanical Engineers on Friday, October 21, 1921

over a large number of years is essential, the alloys may be regarded as stable.

IV (b). Stability of Dimensions.—Some years ago considerable difficulties were experienced by manufacturers on account of serious changes in the dimensions of die-castings, described as "aluminium castings." Although it was found that these castings consisted largely of zinc, it was thought desirable to investigate the stability of zinc-aluminium and copper-zinc-aluminium alloys in the form of complicated castings. In 1913, two similar series of complicated castings were made of a number of these alloys. The materials used included a range of aluminium alloys containing zinc and copper with and without a number of intentionally-added impurities, while at the same time similar castings were made from the purest available aluminium and from ordinary commercial aluminium. Three different dimensions of each of these castings were measured, with an accuracy of 0·0005 of an inch, as soon as possible after casting. One series of castings was then stored in a room in the laboratory, and another was exposed to the weather, the flats, which had been machined on the casting for the purpose of making measurements, being protected by a coating of vaseline. Measurements were taken at intervals of a few months until the castings were forty months old, and they were again measured in January, 1921, about seven and a-half years after they were first made. Except in one case, the largest change found in any of the castings was an increase of three-thousandths of an inch on a dimension of 11 in.; this was found in a casting of pure aluminium.

The results confirm the conclusion that castings of these alloys, whether pure or contaminated with the usual impurities, posses great stability of dimensions, and no serious distortion need be feared. No signs of disintegration were seen in any of the alloys. An interesting observation is that the changes in most of the alloys, but not in all, reached a maximum value about twenty-eight months after the castings were made, and that, after this period, the dimensions returned to a value in most cases very near the original.

IV (c). Fracture under Prolonged Loading ("Season Cracking").—Some of the alloys described in the present report have been found to be liable, in certain circumstances, to a mode of fracture very similar to that which is well-known in the case of brass as "season cracking." In this type of fracture the metal breaks by the separation of the individual crystals from one another. Such failure was first noticed in alloy "A," and it was later found that alloy "E" and its modifications "F" and "G" could also fail in this manner. Microscopic examination showed that rapid failure of this kind is associated with a completely equiaxed microstructure accompanied by smooth, regular crystal boundaries. In the case of alloy "A" such a structure is produced by heating at 450 deg. C. When lower annealing temperatures are used, failure is less rapid; for example, material that has been annealed at 300 deg. C. only fails after many hours' exposure to a relatively high stress. On the other hand, material that has been annealed at a temperature not exceeding 250 deg. C. is found to be immune from this type of failure. Reference has already been made to the fact that the maximum softness in these alloys is obtained by annealing at a low temperature. It is interesting to note that such annealing, applied to this alloy ("A"), does not produce equiaxed crystals. Although material annealed at or a little below this temperature is rendered soft and ductile, it retains an elongated microstructure. Efforts to restore "over-annealed" alloy "A" to a safe condition by thermal treatment alone, were unsuccessful, but it was found possible to do this by hot working. A total reduction of not less than 50 per cent. of the cross-sectional area of the material, provided such reduction is not carried out too rapidly, is found to be sufficient for this purpose; this treatment completely destroys the original equiaxed microstructure and replaces it by a system of elongated grains, whose boundaries are very irregular. Cold working was found considerably to reduce the liability to failure by season cracking, but material which had been seriously over-annealed in the first place could not by cold-work alone be entirely prevented from failing. It must also be remembered that the physical properties of material which has been cold-rolled are not entirely satisfactory. Various modifications in composition were tried with a view to overcoming failure by season cracking. The most promising results were obtained by the addition of 0·5 per cent. of manganese to the alloy. Manganese appears to retard the crystallisation of alloy "A" and to produce a material that is immune from failure of this type unless it is drastically over-annealed. The addition of manganese, however, makes the production of the alloy by forging and rolling more difficult. It was hoped that alloy "E" and its modifications, which contain manganese, would not fail in this way. This hope was not completely realised; in order to develop the best properties in these alloys it is necessary that they be quenched and "aged," and during the process of heating, preliminary to quenching, a certain amount of recrystallisation takes place. Heating for 30 minutes at 400 deg. C. gives material with a microstructure by no means equiaxed, a result of which is due to the retarding influence of manganese. A number of samples, however, after this treatment, failed by intercrystalline fracture after prolonged exposure to stress. If the quenching temperature is reduced to 375 deg. C. or still more certainly to 350 deg. C., failure in this manner is eliminated.

In the case of alloy "Y," failure by season cracking has not been observed, and although a large number of samples have been tested under severe conditions, in no case did any of them crack in this way.

IV (d). Corrosion.—A number of test-pieces of zinc-aluminium and copper-zinc-aluminium alloys have been exposed to sea water for periods up to 448 days. Two particulary interesting observations were made as a result of these tests. In the first place, machined surfaces of binary zinc-aluminium alloys were found to be practically immune from corrosion in sea water, whereas those portions of the test pieces which had not been machined were appreciably corroded. In the second place, the addition of copper to these alloys increases the corrodibility in a very marked degree, whether the surface be machined or not. On the other hand, rapid corrosion does not occur when the ternary alloys are exposed to air, and particularly when they are not exposed directly to the weather. Samples of these alloys have been used indoors for a number of years without the slightest sign of deterioration.

Alloys "A," "E," "F" and "G."—These materials cannot be exposed to sea-water or even to weak saline solutions such as tap-water for any considerable time without undergoing serious corrosion, ultimately leading to complete disintegration. Careful observation with the microscope has shown that corrosion of these alloys, and particularly of alloy "A," follows the crystal boundaries, but in rolled material it shows a preference for boundaries running parallel to the direction of rolling. This gives rise to a condition of lamination, or exfoliation, which is peculiar to these materials. They do not appear to be subject to atmospheric corrosion to any marked extent.

Alloy "Y."—Both in the cast and rolled condition, this alloy possesses considerably better powers of resisting corrosion, even when exposed to sea water, than any other alloy described in this report. The difference between this alloy and alloys "A" or "E" is so great that quantitative data are unnecessary. The difference between this alloy and Duralumin is not so marked, but in several instances that the authors have observed there can be no doubt as to the better behaviour of alloy "Y." This result was unexpected on account of the high magnesium content. The low corrodibility may, however, be due to the fact that this alloy, in the heat-treated condition, contains no free $CuAl_2$.

SECTION V.—Constitution of the Alloys.

V (a). Alloys of Aluminium with Zinc and Copper.—The portion of this ternary system which has been examined covers the range of alloys containing up to 25 per cent. copper and 45 per cent. zinc. The primary constituent over practically the whole of this range of composition is a solid solution of copper and zinc in aluminium. Over a small portion of this range, namely, in the alloys having a high zinc and copper content, the compound $CuAl_2$ is the first constituent to separate from the molten alloy. The second stage in solidification, except in alloys containing only small amounts of copper, consists in the deposition of a binary complex of $CuAl_2$ and aluminium. The temperature at which this separates becomes lower as the zinc content increases.

The compound Zn_3Al_2, which decomposes at about 250 deg. C., is also found in a portion of the system. The addition of copper to zinc-aluminium alloys lowers the zinc concentration at which this compound first appears. The solubility of the compound $CuAl_2$ in the solid alloys has also been determined. In pure copper-aluminium alloys about 5 per cent. of this compound will dissolve at 500 deg. C., and about 3 per cent. or less at room temperature. The addition of zinc reduces the solubility of this compound slightly.

V (b). Iron-aluminium Alloys.—The constitution of alloys containing up to 20 per cent. of iron has been determined. Over this range of composition the alloys consist of aluminium and a compound of $FeAl_3$, which form a eutectiferous series. The eutectic contains 2 per cent. of iron and melts at 648 deg. C. The liquidus rises rapidly with increase of iron content above the eutectic composition, and an alloy containing 20 per cent. of iron is not completely molten at a temperature of 1,000 deg. C. $FeAl_3$ is practically insoluble in solid aluminium, and no sample which the authors have examined is quite free from particles of the free compound.

Silicon-aluminium Alloys.—Silicon and aluminium form a simple eutectiferous series. The eutectic contains 10·5 per cent. of silicon and melts at 570 deg. C. About 1·5 per cent. of silicon will dissolve in solid aluminium. The addition of silicon increases the strength and hardness of aluminium very appreciably. For example, the tensile strength rises from 4 tons per sq. in. in the case of the pure metal to nearly 7 tons per sq. in. in the alloy containing 1¼ per cent. of silicon. With further increase of silicon the rise in strength is much less rapid.

Silicon-iron-aluminium Alloys.—Alloys containing up to 8 per cent. of iron and 8 per cent. of silicon have been examined. A new constituent has been observed, but its composition has not been ascertained. It is, however, found to occur in practically all the alloys examined. It forms with iron and silicon a ternary eutectic, the melting point of which is 570 deg. C.

V (c). Aluminium-magnesium Alloys.—The constitution of this series of alloys has been determined, and it has been shown that two compounds, Al_3Mg_2 and Al_2Mg_3, exist. These compounds form a eutectiferous series with each other, and with aluminium and magnesium respectively.

Aluminium-magnesium-silicon Alloys.—Alloys containing up to 35 per cent. magnesium and 11 per cent. silicon have been examined. Magnesium and silicon in these alloys form a compound Mg_2Si. This compound and aluminium form a simple binary system with a eutectic which contains 13 per cent. of the compound and melts at 590 deg. C. Mg_2Si and aluminium form ternary eutectiferous series of alloys with both silicon and magnesium. The melting points of the ternary eutectics are 560 deg. C. and 450 deg. C. respectively.

Alloys belonging to this system are relatively soft after they have been quenched from a high temperature, but they gradually become harder. This age-hardening is practically complete after a few days. This property of "age-hardening" has been definitely correlated with the constitution of the alloys. The compound Mg_2Si is found to be much more soluble at a high temperature than it is at room temperature. For example, in the binary system Mg_2Si—aluminium, about 1·6 per cent. of the compound is soluble at a temperature of 500 deg. C., whereas not more than 0·5 per cent. remains in solution after the alloy has been slowly cooled to normal temperature. The addition of excess of magnesium reduces the solubility of this compound, but excess of silicon has little effect.

It has been found that the amount of age-hardening in alloys quenches from an elevated temperature (500 deg. C.) is approximately proportional to the difference in solubility of the compound Mg_2Si at the quenching temperature and at room temperature. The effect of "ageing" at temperatures higher than that of the atmosphere has been studied, and it has been found that still further increases in strength and hardness can be obtained by the use of a slightly elevated ageing temperature.

The profound influence of heat treatment on these alloys is illustrated by the following results:—A forged and rolled alloy containing 0·6 per cent. of magnesium and 0·6 per cent. of silicon had a maximum strength of 7 tons per sq. in. as slowly cooled, 14 tons per sq. in. after quenching from 500 deg. C. and ageing at room temperature, and 20 tons per sq. in. after quenching at 500 deg. C. and ageing at 200 deg. C.

V (d). Age-hardening of Silicon-magnesium-aluminium Alloys containing Copper, Zinc or Nickel.—The effects of copper, zinc and nickel on the age-hardening produced in aluminium by the compound Mg_2Si have been studied. Three per cent. of copper reduces the solubility of the compound Mg_2Si to a slight extent, about 0·9 per cent. being soluble at 500 deg. C. Considerable "age-hardening" is, however, obtained. The action of zinc is similar, about 15 per cent. of this metal having the same effect as 3 per cent. of copper. Nickel is without much effect on the solubility of the compound Mg_2Si, the maximum solubility and hardening effect being found with a magnesium silicide content of about 1·3 per cent. The improvement in properties which can be obtained by making use of the hardening effect of Mg_2Si are indicated by the following results:—A 3 per cent. copper alloy containing 1 per cent. of magnesium silicide has a hardness of about 70 when slowly cooled. This is increased to over 100 by quenching and ageing at room temperature, and to 130 by further ageing at 200 deg. C. The hardness in this case is nearly doubled by heat treatment. Similarly, in the case of an alloy containing 3 per cent. of nickel, together with 1·3 per cent. of magnesium silicide, the hardness is increased from 35 in the slowly-cooled specimen to 70 in the specimen quenched and aged at room temperature, and to nearly 100 by further treatment at 200 deg. C. This represents an increase of 180 per cent. on the original hardness.

Further tests are described in which more complex alloys, similar to commercial "Duralumin" and alloy "Y," were used. In these alloys also the correct regulation of the magnesium silicide content gives improved mechanical properties. A similar age-hardening in copper-aluminium alloys is also described.

A Large Lifting Magnet.—What is probably one of the largest electric lifting magnets ever constructed has recently been supplied to a British steel works by the Witton-Kramer Electric Tool and Hoist Works from their Witton Works, near Birmingham. The magnet is 66 in. in diameter, weighs 58 cwt., and is capable of raising a load of 50 tons. It is used in connection with a plant for handling and breaking scrap metal and delivering it to the charging box for furnace filling, and is handled by a 25-ton overhead crane. The scrap consists largely of skulls—the linings of the steel ladle—which are chiefly composed of slag and are of very poor magnetic quality. The skulls are unloaded by the magnet and placed in the breaking pit. They are broken by means of an 8-ton ball which, whatever its position, naturally presents the same surface to the magnet. No centering device is necessary, and the magnet lifts the ball practically on point contact. After the scrap is broken the metal is lifted by the magnet and fed to the charging boxes.

Coal in China.—China's coal output in 1920, according to a well-known mining expert, was as follows, says the Chinese Government Bureau of Economic Information:—

	Tons.
Manchuria	1,025,000
Chihli	2,280,000
Shansi	4,025,000
Shensi	500,000
Kansu	500,000
Honan	1,000,000
Shantung	800,000
Szechwan	500,000
Yunnan	300,000
Kweichow	250,000
Chekiang	10,000
Kiangsi	200,000
Hunan	200,000
Kiangsi	50,000
Kwangtung	10,000
Others	10,000
Total	11,660,000

THE INSTITUTION OF CIVIL ENGINEERS.

Presidential Address of William Barton Worthington.*

In taking the chair as your president in this home of my profession, what is uppermost in my mind is the hope that I may be able to make some little return by service to our Institution for what it has been to me in my professional life, and so to justify your election of me for a second time when my illness had prevented my taking the chair to which you elected me four years ago. I recognise that you have treated me with generous consideration, and I thank you for it. I enter on the office with a deep sense of responsibility, and realise that it is only with the support and help of my colleagues on the council that I can hope to discharge its duties.

Now let me clear the ground; it is with some diffidence, that I begin this address. Great changes are coming into force under the Railways Act, and the railway companies of Great Britain are about to start a new and deeply interesting chapter of their history; but as my own active connection with a railway company came to an end four years ago, this is not a subject on which it is suitable for me to enlarge. I may, however, express the hope that there will be, as the result of the new situation some considerable developments in standardisation of railway practice, for which there are ample opportunities in matters both great and small. One important step in this direction has already been made in the reports to the Minister of Transport of Sir Alexander Kennedy's Advisory Committee on Electrification of Railways.

The whole of my professional life has been that of a railway engineer. Such a life does not run in any narrow groove. With canals and reservoirs, docks and harbours claiming attention in addition to the railway work proper (new works, maintenance and Parliamentary) the railway engineer has a great variety of experience and work. Then, in addition, there is a large staff for the maintenance of the works under his control, and in recent years a great deal of his time and attention has had to be given to labour questions, an exacting responsibility.

It is often said that the new works side of the railway engineer's department is more attractive, and offers greater opportunities, than the maintenance side. While there is no doubt that a man who is to be a railway engineer must have his training on the carrying out of new works, there can also be no doubt that he will be a much more satisfactory designer and constructor of works if he has had experience in the maintenance of such works on lines open for traffic. He will, in his maintenance experience, learn what not to do, as well as some things to do, as a designer or as a resident engineer carrying out new work. No doubt in a well-organised engineers' department there will be means provided to bring to the notice of the drawing office any points which arise in maintenance which make a particular design unsuitable or susceptible of improvement, and such improvements gradually become standard practice. Thus, for example, the steel bridge floor designs of to-day are, as a result of maintenance experience, a great improvement on those of an earlier date. It is now a rule that any wrought-iron or steel work which is not permanently protected from the action of air and damp shall be readily accessible for painting when required. Similarly the best bridge floors of to-day are provided with means for disposing of the rainfall on the bridge without annoyance to those who pass under them, an annoyance always accompanied by deterioration of the structure. These, it may be said, are small matters, but efficient maintenance is made up of small matters, and it is the attention to small matters which prevents big accidents. As the result of maintenance experience the permanent way has been continuously improved until—with perhaps the exception of the rail joint—it leaves little to be desired to promote smooth running on a well-maintained road, so far as the design is concerned. Given the best design, however, the smooth running depends on the divisional engineers and their maintenance staff. Further advance in the direction of longer life for the rails is to be looked for rather in the material and manufacture than in increased weight of rail.

I have great sympathy with the divisional maintenance engineer on a railway. Much of the most difficult and responsible work on which the safety of the traffic depends is quietly carried out under his supervision, and makes little show in the public eye unless something goes wrong. He is responsible for the safety and proper maintenance of the permanent way and works on his division; he carries out the smaller class of new works, watches the progress of the working of minerals under or affecting the railway, makes good the resulting subsidence, and fixes the speed to which trains shall be limited in passing over portions of the line at which speed has to be reduced for safety. Those who have had experience of the surface results from the working of the coal and fireclay of the coal measures, the oil shales, the Furness hematite, the East Lancashire flag-rock and of the brine pumping in salt areas will appreciate correctly the constant watchfulness required. Then again, the railway maintenance engineer, if he has charge of a defective brick or masonry tunnel, will gain invaluable experience in keeping it in order, though many of his Sundays may have to be spent in acquiring it. Such experience will be of the greatest use to him when it becomes his duty to construct a tunnel on a new line. He will have learnt how not to do some things and will see that they are done rightly in his new work. Part of his duty is the supervision of the renewal and strengthening of bridges to meet the greater loads which the constantly increasing weight of the locomotives and their individual axle-loads has brought upon them. When it is remembered that George Stephenson's engine, the Rocket, which won the prize at the competition at Rainhill in October 1829, prior to the opening of the Liverpool and Manchester Railway, weighed only 4½ tons, including fuel and water, and that engines are now running at greatly increased speeds with five times this total load upon one pair of wheels, it is plain that much strengthening of structures must have been required in the meantime. It says much for the design and workmanship of the stone and brick bridges and viaducts of the early railways, that they have withstood so well the enormous and unforeseen increase in the demands made upon them. On the other hand, it is not surprising that in many of the old stone viaducts the spandril walls carrying the parapets and retaining the filling over the haunches and backing of the arches have been unable to withstand the continual pounding of these increased weights and have had to be rebuilt of greater thickness and strength.

A short history of one of these early structures, which illustrates some of the problems of maintenance, may be of interest. It is one of the graceful laminated timber-arch viaducts which Joseph Locke (President 1857–59) constructed on a number of his railways, for instance, on the Manchester and Sheffield, the Lancaster and Carlisle, the Scottish Central, and the Western of France. In April, 1840, my father was in the third year of his six years' pupilage to Locke. One day towards the end of that month Locke came into the room where he was working and handed him a letter and sketch from his assistant, W. B. Buddicum,* giving some particulars and dimensions of the laminated timber-arch viaducts which John and Benjamin Green† had recently erected for the Newcastle, North Shields and Tynemouth Railway, and instructed him to get out drawings for viaducts on the same principle for the Manchester and Sheffield Railway. My father entered on the work with enthusiasm. May I quote from his diary? "May 13, 1840. Drawing timber viaduct 120-ft. span and 40-ft. rise for the Sheffield Railway. At office till 12 o'clock." "May 14, 1840. Drawing timber viaduct. At office till 10 p.m." These diary entries show that a hard-working pupil in those days had very good work and plenty of it. The lofty Broadbottom and Dinting Viaducts on the Manchester and Sheffield Railway (now Great Central) for which these drawings were made, were shortly afterwards constructed by A. S. Jee, M.Inst.C.E.,‡ resident engineer on the railway. Subsequently, in 1845, as resident engineer under Locke on the Lancaster and Carlisle Railway my father constructed one of these viaducts over the River Lune at Lancaster. This viaduct carried the main line traffic of the London and North-Western Railway to Scotland. When that company acquired the Lancaster and Carlisle it was decided that the timber arches should be replaced by an iron structure. The viaduct would have continued to carry the traffic safely for some years longer in spite of the increased weight of locomotives since its construction, but a large oil-works had been established in its immediate vicinity and the increased risk of the destruction of the bridge by fire, which would have severed the connection of the London and North-Western with Scotland, was the determining factor. So in 1865–66 my father replaced the timber arches after a life, somewhat prematurely terminated, of twenty-one years, by a less inflammable structure consisting of continuous wrought-iron box girders carried by the original stone piers with cross-girders and a timber floor. By the courtesy of Mr. Trench, chief engineer of the London and North-Western Railway, I am able to complete the history of the bridge to the present time. The old box girders and cross-girders still continue in use, but the timber floor was replaced in 1894 by steel beams carrying longitudinal chair timbers and floor plates. This history speaks well for the careful maintenance of the old wrought-iron superstructure which has been in use for fifty-five years. Mr. Blundell, chief engineer of the Great Central Railway, informs me that the two viaducts on the Manchester and Sheffield Railway (now Great Central) have a somewhat similar history, the original timber arches having been replaced by wrought-iron box girders after a life of sixteen years (1844–60),§ and further strengthenings having taken place in 1893 and 1917. I am indebted to Mr. Bengough, chief engineer of the North-Eastern Railway, for the history of Green's Ouseburn Viaduct, the prototype of these bridges; it was brought into use in 1839. In 1867, after a life of twenty-eight years, the timber arches were renewed in wrought-iron, the timber decking being retained in use until 1896, when it was renewed with wrought-iron. The history of these bridges raises the question how far it was a sound proposition financially to erect these large span timber arches rather than a more permanent superstructure in the first instance. No doubt, there was a great saving in first cost in Locke's Lune Viaduct, with its timber arches, as compared with the viaduct with elliptical stone arches of similar span, which Vignoles erected over the Ribble at Preston at about the same time for the North Union Railway, which now, like the Lancaster and Carlisle, is part of the London and North-Western main line to Scotland. On the other hand, the cost of maintenance of the Lancaster structure must have been much the greater of the two. There is no likelihood, however, of the maintenance records for these two viaducts from the date of their construction being still in existence. In considering the suitability of these large span timber arches the financial conditions at the time of their construction must be borne in mind. The Lancaster and Carlisle Railway was the last link in the West Coast route through England, and it was important to push it through as quickly as possible; whereas, at the time when the substitution of iron girders for the timber arches was decided upon the line was earning large dividends.

This is ancient history, and perhaps I have dwelt too long upon it, but it is typical of many of the problems of railway construction and maintenance, and illustrates the continuous competition between the locomotive and the fixed structures.

Our predecessors, the pioneers of early railways, were far-sighted men, but even they could not grasp fully the stupendous changes which the new facilities for transport would bring about; they hardly realised that they were putting the finishing touches to the industrial revolution, which, for better for worse, has transformed our country.

Hence, much of the railway engineer's work latterly has been to fit the original work to modern conditions—widening and enlarging, doing away with level crossing of road and railway, and railway and railway, strengthening bridges and fitting suburban lines for electric working. There were giants in those early days, and one cannot accuse them of lack of vision without being uncomfortably conscious that possibly we ourselves are lacking in vision of the great changes ahead of us, and are possibly not very ready to open our eyes to them. Are not prospects opening out before us not less vast than those of 100 years ago? For the moment economic difficulties seem to block the way, but who can say what new applications of the great sources of power in Nature may change our present conditions even more than steam has changed those of the past? It may well be that the children of to-day will live to see, as a result of new industrial developments, an unpolluted atmosphere, an England of clean and shining towns, and once again "England's green and pleasant land."

I wish now to refer to some matters concerning our Institution and our membership of it, and what it is that we mean by a Civil Engineer, and in doing so I shall have to touch upon some points which are familiar to you from the records in the Proceedings of the Institution and the reports of the council.

The earliest recorded use of the name Civil Engineer which I have been able to trace is 150 years ago, on March 15, 1771, in the minute recording the formation of a society or club which later gave rise to the Society of Civil Engineers now known as the Smeatonian. At this meeting it was agreed "that the Civil Engineers of this Kingdom do form themselves into a Society." The minute was signed by Thomas Yeoman (in the chair), John Smeaton, who had designed and constructed the Eddystone Lighthouse twelve years before the date of the meeting, Robert Mylne of the New River Company, who had completed his Blackfriars Bridge two years before, and four others. In the course of the following twenty-one years the membership reached a total of 65, and included William Jessop, a pupil of Smeaton, James Golborne, Robert Whitworth, a pupil of Brindley, Matthew Bolton (Boulton), John Rennie, James Watt, and Joseph Priestley. In 1793 the society was reconstructed with a stricter constitution. Under this there were three classes of members. The first were ordinary members described as "real engineers employed as such in public or private service." Among these were William Jessop, Robert Whitworth, John Rennie, Robert Mylne, and James Watt. The second and third classes were honorary members. Smeaton had agreed to join the new society, but died before its first meeting.

It is interesting and material to compare the dates of the organising of the Civil Engineers just described with the dates of the development of the status of military engineers at about the same time, or a little earlier. At the beginning of the eighteenth century the functions subsequently transferred to the Royal Artillery and Royal Engineers were performed by the Board of Ordnance with its engineers. These were the men who at that time bore the name of engineer, but their work was purely military. In 1716* a regular corps of engineers was formed, still however under the Board of Ordnance, while the artillery was placed on a proper footing as a separate establishment. In 1757* the engineers first received commissions and thus obtained military rank, and in 1787* the corps became the Royal Engineers. It will be noticed that a few years after the Military Engineers for the first time received commissions "the Civil Engineers of this kingdom," as the little meeting of 1771 described itself, founded their first society, and that six years after the Military Engineers attained their position and title of Royal Engineers the "Society of Civil Engineers" was revived on a more strictly professional bases, and in the same year, 1793, Smeaton, in the preface to his account of the Eddystone Lighthouse, speaks of "my profession of a Civil Engineer."

This growth in strength and status of the Military Engineer was taking place at the same time as the increasing demand for the engineer on the civil side of life was crystallising the need for association and improvement in status of the men who were practising in such work. It is perhaps too much to say that the one chain of events was consequent upon the other, but no doubt both were influenced by the progress of the industrial revolution of which the development of engineering was an integral part, and undoubtedly the assumption of the description Civil Engineer was by way of distinction from the Military Engineer who had, up to that time, monopolised the title of Engineer.

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* Delivered at the Institution, November 1, 1921.

* M.Inst.C.E. (1845–87). Author of the notes on the various Schools for Engineers in France in the Institution's "Education and Status of Civil Engineers," 1870.

† See paper by Benjamin Green, M.Inst.C.E. Proc. Inst. C.E., vol. v., page 219.

‡ See paper by A. S. Jee, M.Inst.C.E. Proc.Inst.C.E., vol. v, page 216.

§ See paper by Sir William Fairbairn, M.Inst.C.E., Proc.Inst.,C.E., vol. xxii, page 327.

* Major-General Whitworth Porter, R.E., "History of the Corps of Royal Engineers," 1889.

Twenty-five years later—January 2, 1818—the Institution of Civil Engineers was founded. The founders were, as pointed out by Dr. Tudsbery in his record of the origin and progress of the Institution of Civil Engineers, read at the centenary meeting on January 8, 1918, for the most part men engaged in the construction of machinery, and their use of the expression "Civil Engineer" in the title of the new Institution was in accord with the distinction drawn then and subsequently between "Civil" and "Military" engineers.

At this date engineering was opening out in all directions in the United Kingdom. The country was being covered with a network of canals; the high roads were being thoroughly improved; little mineral railways were being laid out here and there, and Blenkinsop-Hedley and Stephenson had steam locomotives working upon them; Symington had tried his steam barge, the Charlotte Dundas," on the Forth and Clyde Canal successfully, and six years earlier the SS. Comet had commenced running of the Clyde; river navigation and harbours were being improved. What a prospect for the young civil engineer.

"Bliss was it in that dawn to be alive,
But to be young was very heaven."

Ten years later (June 3, 1828) our Royal Charter of Incorporation was granted embodying the well-known statement of the objects of the Institution and of the "species of knowledge which constitutes the profession of a Civil Engineer."

The wide range of the profession is well illustrated by the present constitution of the Council of the Institution, which includes members practising in more than half-a-dozen branches of engineering, each of which has an important institution devoted to its special interests. On the other hand a narrower view of what is meant by civil engineering has been made familiar to the public and to students by the action of some universities and colleges in establishing parallel courses of civil engineering and mechanical engineering, and again very recently by some railway companies adopting the titles of Civil Engineer and Mechanical Engineer for two chief officers. It is, perhaps, too late to overtake this modern usage, but that does not affect the meaning of the words "Civil Engineers" in the name of the Institution. There is no doubt that at its birth, at the time of the granting of the Royal Charter, and throughout its 103 years of vigorous life and action, these words in its title have stood for civil engineers in every branch of professional engineering with the exception of the military.

The Institution bye-laws now prescribe a number of alternative courses by which a man who has or who has not gone through an engineering college course and taken an engineering degree may acquire that practical training which he must have before he can become a civil engineer and an Associate Member of the Institution. About half a centruy ago, when the question had to be decided whether an English boy should go through a college engineering course before being articled as a pupil to a civil engineer, Owens College, Manchester, was the only college in England, outside London, where such a course was to be obtained, though Glasgow (Professor Rankine) and Edinburgh (Professor Fleming Jenkin), and Trinity College, Dublin, also provided them. Still,it was a question at that time whether it might not be best for a boy to go to one of the great foreign Polytechnic schools, Zürich, Carlsruhe, Stuttgart, &c.* No such question need arise to-day; there is no lack of the best scientific preparatory training for engineers in Great Britain and the Dominions, nor is there any need for a British boy to consider going abroad for lack of choice of the best educational facilities at home.

In bringing about this result the Institution bore a part by the issue in 1870 of the very valuable report on "The Education and Status of Civil Engineers in the United Kingdom and Foreign Countries."

As a result of experience, commencing with my own pupilage, I am of opinion that the best way for the young engineer to obtain his practical training is by means of pupilage after graduation at one of the many universities, old or new, which have engineering schools. The relation between a chief and his pupil is a very satisfactory one for both parties, always remembering that both have their obligations. Possibly I have been specially fortunate, but it has not fallen to my lot to have to do with pupils who were not eager to do their best to learn all they could and make themselves as useful as possible to those with whom they had to work. I have had the happiness to make lasting friendships among those who have stood to me in that relation.

In the old days a boy often went straight from school into his pupilage to a civil engineer. To-day, if well advised, he takes his university or college course of at least three years before doing so. This affects the financial question, with the result that men otherwise suitable in character and education for the profession of civil engineer not infrequently cannot afford the premium for a pupilage.

An arrangement, however, adopted for recruiting the engineer's professional staff to suit the conditions of a great railway company, has been found to work well both for the young engineer and for the company, and meets such cases. Young men who had taken a good university degree were, on leaving college, taken on to the staff at a small salary, which was raised at the end of each year of service. They undertook to remain with the railway company for three years, but the company could terminate the engagement at any time during the three years. Special facilities were given them for becoming acquainted with such varieties of work as the engineer's office and works afforded. They were employees of the railway company, subject to its conditions, and not personal pupils of the engineer. It had been found by experience elsewhere that the condition to stay with the company for three years was necessary, as otherwise, after a year or so, when the advantage was nearly all on one side, the young man might obtain a nomination abroad, on the ground that he had gone through an engineering college course and had had a year's training on the staff of the engineer of an English railway. That the arrangement I have described was satisfactory to the young men was shown by the fact that under these conditions high-grade university men were forthcoming for such vacancies as occurred from time to time.

It not infrequently happens that a man on leaving college, after having taken a degree in engineering, takes a salaried position of a kind or under circumstances which preclude its being accepted as training to qualify for corporate membership of the Institution, with the result that such admission must be long postponed if ever attained. Now that the Institution has decided to permit men while at college to be nominated for studentship of the Institution by professors under whom they are working, and who are corporate members, without the condition hitherto insisted upon that the student should have in advance made arrangements for his practical training, I venture to hope that they will exercise care to see that those of their students who intend in due course to become corporate members of the Institution understand the importance of arranging for practical training as civil engineers under one or other of the alternatives set forth in the by-laws.

Out of all the endeavours of many members to help the Council to further the interests of the Institution, emerges a substantial feeling that the effort required—and often the sacrifice—to attain competence in civil engineering, is ill-requited by many employers, and especially by the State and public bodies. Requests are often addressed to the Institution that its influence may be used to secure some improvement of the position of members engaged in particular services—an object difficult enough to fulfil without being told to mind one's own business as regards commercial relations between employer and employed.

This does not, however, dismiss the question. It is there, and it must be admitted it has not been answered effectively. It will be known through the medium of Council Reports and similar statements, to those who read them, that the Council have, in such ways as appeared to be justified and prudent, sought to improve the position of members of the Institution who serve under public authorities of various kinds—an improvement which, if secured, would quickly reflect on the status of civil engineers in other avocations.

But here we must pause for a moment to inquire—what is the real view of those who compose the Institution, as to its definite and avowed objects? Is it in these days to continue to pursue its primary intention for which it was founded and chartered, to advance the knowledge and skill of its members, and incidentally to approve their qualifications in those respects, thereby promoting the status of the civil engineering profession as a whole, or is it to devote itself largely to the individual interests of its members?

There is undoubtedly a school of thought which measures the value of our Institution by some tangible gain or personal benefit. The man who thinks he owes least to the Institution should remember that though he may practise successfully the profession and art of a civil engineer, yet it was the Institution that established it, and that it is very largely the prestige of the Institution that lends to-day an authority to those who claim the title of civil engineer, whether they are members or not.

It may not be according to precedent for a President to recognise that the subject of emolument claims a serious share of the attention of those whose first object is to raise and advance their profession. But it is useless to shut one's eyes to this.

Whether by direct representation that civil engineers' services are worth more than is sometimes offered for them, or by the indirect mode of restricting the employment of persons whose claims to civil engineering competence are thought to be doubtful—the result widely sought for is the same, and we must all be in sympathy with the idea, however unpromising its attainment by those means may appear to be to long experience.

The clear practical way of assuring to members of the Institution a full share of the benefits it has conferred, and can yet confer, upon the civil engineering profession, is to secure that the term which designates that profession, and has obtained its high value through our Institution, may be understood by all and sundry to mean a person found by it to be qualified. Such was the success of the Institution in its earlier days in establishing the profession of civil engineering, and so little was it careful to safeguard its title, that a simple description of profession then formally assumed and rendered valuable by its efforts, cannot now be claimed exclusively by its members, who, it appears, must accordingly adopt some modified term if they wish to distinguish their calling clearly.

It is impossible to insist too strongly that training is of the essence of the matter that lies at the root of all this. It must be obtained in the civil engineer's office and in or upon engineering works. If a man is to be a civil engineer he must have, in the words of the charter, "that species of knowledge which constitutes the profession of a civil engineer," to promote which the Institution was founded. I claim for the Institution that it has from the very first made its object the improvement of the profession of civil engineering, and by profession I mean the possession of particular knowledge. The question naturally arises—what is this particular knowledge, and what is the training essential to its acquisition? The answer must be that the Institution of Civil Engineers is the authority to determine that. It is the original and only body in Great Britain constituted by act of the Crown to promote the profession of civil engineering, and its rules in regard to education and practical training have been laid down with the greatest care by those most competent to judge what is required in these matters. Civil engineering is not born in man, nor can he have it thrust upon him by means of a suitable appointment, but he must achieve it through education, training and experience. Until he has done this, he cannot claim to be a civil engineer under our Charter and By-Laws.

It is probably due largely to the general likeness of this education and training that civil engineers in all parts of the word form the community we know. There has been advocated some enlarged co-ordination of the aims of bodies whose interests are associated with various special branches of engineering, and this important question will no doubt receive the very careful consideration it calls for. Meanwhile, the unity of our own Institution is necessarily our first care, and I shall feel indeed glad if what I have tried to set forth may help to strengthen that community of view and aim on which such unity depends.

* See "The Education and Status of Civil Engineers in the United Kingdom and Foreign Countries." Institution of Civil Engineers, 1870.

CATALOGUES.

Injectors.—A descriptive catalogue of their re-starting injector comes from Messrs. G. Dikkers and Co., Hengelo, Holland.

Hand Cranes.—A further small catalogue of hand-operated hoisting and travelling cranes has been received from Messrs. Herbert Morris, Limited, Loughborough.

Electric Switches.—The Park Royal Engineering Works, Limited, London, N.W. 10, send a pamphlet containing a number of illustrations of their latest designs in switch gear and instruments.

Oil Engines.—A great many facts and figures relating to the financial economy of oil engines are given in a little pamphlet received from Messrs. Ruston and Hornsby, Limited, Lincoln.

Colliery Switch Gear.—The General Electric Company, Limited, Magnet House, Kingsway, London, W.C. 2, send us a special catalogue of flame-proof switch gear for collieries.

Celluloid.—A leaflet from the British Cellulose and Chemical Manufacturing Company, Limited, 8, Waterloo-place, London, S.W. 1, describes a new material made from cellulose-acetate, which has much the same working properties as celluloid and is non-inflammable.

Electrical Machines.—A price list of alternating-current motors, direct-current motors, motor generators, dynamos and starting gear giving a very large range of powers from ¼ b.h.p. to over 60 b.h.p., is to hand from Messrs. Higgs Brothers, Sand Pitts, Birmingham.

Bench Lathe.—A complete catalogue of the Carson bench lathe, with screw cutting, chasing and grinding attachments, and also countershaft and foot-motor, comes from Messrs. Charles Churchill and Co., Limited, 9, Leonard-street, London, E.C. 2.

Turbine Blades.—Messrs. C. A. Parsons and Co., Limited, Newcastle-on-Tyne, have forwarded a copy of their booklet explaining the construction and adjustment of their end-tightened reaction blading, and quoting test figures to prove the mechanical durability and steam economy attained by it.

Water Wheels.—An interesting catalogue of water wheels comes to hand from Messrs. Carrick and Ritchie, Edinburgh, and will be especially useful for the large number of tables stating the horse-power developed for various heads and volumes of water. It is a catalogue easy to consult when a few local conditions are known, and the number of sizes tabulated indicates that this firm is prepared to meet a large range of requirements.

Steam Tractors.—Messrs. Marshall, Sons and Co., Limited, Gainsborough, send us a copy of their catalogue of road engines conforming to the legally defined "steam tractor." These engines give about 20 b.h.p. when belt-driving at economical load. The road wheels are 60 in. in diameter and 12 in. wide on the rim. The fast speed is 5 m.p.h. and the slow speed half that figure. The weight in working order is about 7½ tons. The boiler work is of high quality and design to obtain economical working, and two types of engine are available: a compound for long runs working at 200 lb. per square inch, and a simple working at 180 lb. per square inch. The controls have been carefully designed for convenient operation.

LOW-PRESSURE TURBINE BLADING FAILURES IN DESTROYERS.*

By Lieutenant-Commander D. F. Ducey, U.S.N., Member.

(*Concluded from page* 612.)

Method of Test.

Samples for chemical analysis were taken from each unit of blades received (Table I). Representative specimens from every piece received were taken for metallographic examination, with regard to both non-metallic inclusions and grain structure. A number of blades from each of the three vessels were machined for tension test (Table II). As a test for brittleness a number of the blades were machined for bend tests and others were

* Reprinted from the Journal of the American Society of Naval Engineers, and slightly abstracted.

bent as received. The results of these tests are illustrated in Figs. 11 and 12. Additional bend tests were made on specimens machined to various shapes, approximating turbine blades. The results are shown in Fig. 13. A large number of impact-shear tests were made on specimens machined from the blades' roots. Some of these were given various heat treatments to study the tendencies of this material toward brittleness. The results are given in Table III.

To study the effects of the blade design upon apparent brittleness of the material, a number of bending test experiments were made on specimens of different shapes. Two different materials were used, one of Class "Ac" steel, containing about 0·6 per cent. carbon, and the other of Class "An," or 3½ per cent. nickel steel. The shapes of the specimens are shown in Fig. 14. These were arranged to show the effects of the "notch," and of sharp edges, on the tendency to fracture. The specimens, after bending are shown in Fig. 13.

Results of Metallographic Examination.

Photographs J-1 to J-4 (Fig. 14), illustrate typical structures of the blades from the 175 as shown in Fig. 2. J-1 to J-3 show the structures of two damaged blades. Each was taken near a surface of fracture. The structures are uniform and the grain size varies from moderate to fine. J-3 shows the unetched surface of the same specimen shown on J-2. This specimen contains considerably more than an average quantity of non-metallic inclusions. This might be considered a limiting condition in these blades, since most of the others are somewhat cleaner. J-4 shows that the structure of the spare blade from the third stage is uniform and of small grain size, similar to that of the damaged blades.

Results of Impact Tests.

The impact tests were made according to a method developed at the Experiment Station, published in the "Proceedings of the American Society for Testing Materials, Vol. XVIII., Part II., 1916." This method consists of shearing an unnicked specimen by means of a swinging pendulum. The residual energy in the pendulum is measured by the height to which it swings after breaking the specimen. The energy required to break the specimen is taken as an index of impact-shear toughness. The size of the specimen is ⅜ in. by ¼ in., and the gripping vice is so arranged that one specimen can be moved along and sheared a number of times and the average results used.

Some specimens for impact were given various heat-treatments in order to determine the possibility of producing "temper brittleness" in these blades. The heat treatments are listed below :—

	Treatment letter.
1. *Annealed to* 1,500 *deg. F.*—	
Reheated to 968 deg. F., cooled in furnace	A
" 968 " " water	B
" 1,148 " " water	C
" 1,148 " " furnace	D
2. *Quenched in oil from* 1,500 *deg. F.*—	
Reheated to 968 deg. F., cooled in furnace	A′
" 968 " " water	B′
" 1,148 " " water	C′
" 1,148 " " furnace	D′
3. *Annealed at* 1,500 *deg. F.*	E

Table III. gives the results obtained on material as received and on heat-treated material. In each case, the results obtained on a heat-treated specimen are given opposite the results obtained on an untreated specimen from the same blade.

Results of Bend Tests.

The results of the bend tests on specimens machined from the blades to rectangular section are shown in Fig. 11. In most cases the specimens were bent flat through 180 deg. without signs of failure. Two specimens were taken from each of the two blades shown in Fig. 8, which broke while being installed. Three of these failed when bent to about 180 deg. One of the three specimens taken from the third stage of the 280 failed when bent through 180 deg. A number of specimens from the fourth and fifth stages of the 280 showed only small surface cracks when bent through 180 deg.

Of the entire lot of spare blades shown in Fig. 10, only one specimen from the third stage failed, and then only after bending through 180 deg. Two specimens were taken from the eccentric blade shown in Fig. 9, and one of them was given the heat treatment A′. The untreated specimen was bent flat on itself without cracking. The heat-treated specimen cracked when bent through about 170 deg.

Since these tests did not indicate excessive inherent brittleness of the material, bend tests were made on sections of the blades as received, to determine the effect of the blade section shape on the amount of distortion that the specimen will undergo without fracture. A number of blades were bent with the sharp blade edge inward, and others were bent with the sharp edges outward. The results are shown in Fig. 12. Those bent with the sharp edges inward were bent flat without cracking, excepting one which was given heat-treatment A′. This one cracked when bent to about 170 deg. The four blades bent with sharp edge outward showed cracks in every case long before bending to 180 deg. In one case the angle of bend was only about 45 deg.

To show even more convincingly the inability of turbine blade sections to undergo bending without cracking, bend specimens of three different grades of material were machined to the shapes shown in Fig. 14. These specimens were designed to give a comparison of the action of bend specimens with the kinds of test section given in the next column :—

(A) Rectangular cross section.
(B) Rectangular cross section with fillet at the danger section.
(C) Turbine blade section.
(D) Turbine blade section with fillet at danger section.

The materials used were machine steel, Class "Ac" steel, and Class "An" steel. The results are shown in Fig. 13, which shows the angles of bend when cracks were first observed. As was expected, the specimen of rectangular section was bent flat without cracking. The other specimens cracked long before bending through 180 deg., the order of decreasing angle of bend when cracks first appeared being B, C, D. Only a small degree of bending (about 20 deg. to 25 deg.) was required to produce cracks in the D specimens, which were really close approximations of the actual turbine blades.

The specimens E and F in each case showed that the rectangular specimen bent on a diagonal axis could be bent to a greater angle than when bent on an axis parallel to its base.

Discussion of Chemical Analysis.

The chemical composition of the different sets of blades varied considerably. The specifications for the steel blades of the 178 and 175 originally called for chrome vanadium steel, but were later changed to require chrome-nickel steel. The result was that some of the blades were of chrome-vanadium and others of chrome-nickel.

The steel blades tested may be divided into two general classes, regarding chemical composition. The chrome-nickel steel blades contain about 3½ per cent. Ni and ¾ per cent. chromium, and the chrome-nickel vanadium steel blades contain about 1½ per cent. Cr., 0·4 per cent.

TABLE I.—Chemical Analysis.

——	Blade No.	C.	S.	P.	Mn.	Si.	Ni.	Cr.	Van.
175. Damaged blades. (Fig. 2)	19	0·40	0·043	0·027	0·70	0·25	0·42	1·15	0·31
	67	0·41	0·045	0·028	0·70	0·25	0·42	1·15	0·28
	87	0·39	0·043	0·026	0·69	0·25	0·41	1·15	0·30
175. Spare blade	105	0·36	0·045	0·025	0·71	0·33	3·28	0·67	None
178. Damaged blades. (Fig. 3)	125	0·27	0·034	0·007	0·45	0·17	3·31	0·64	None
	189	0·27	0·032	0·006	0·45	0·18	3·28	0·65	None
	176–177	0·30	0·038	0·003	0·39	0·19	3·25	0·64	None
280. Damaged blades. (Figs. 4 and 5)	331–335	0·38	0·048	0·007	0·61	0·15	3·25	0·74	None
	271–275	0·38	0·047	0·003	0·62	0·20	3·23	0·74	None
	300–304	0·39	0·052	0·003	0·67	0·17	3·20	0·74	None
	468–472	0·38	0·051	0·004	0·53	0·23	3·26	0·74	None
280. Roots. (Fig. 7) ..	396–400	0·36	0·051	0·004	0·62	0·23	3·20	0·74	None
280. Blades from third and fourth stages broken while being installed. (Fig. 8)	501–520	0·43	0·036	0·011	0·86	0·29	0·40	1·40	0·06
	521–540	0·43	0·043	0·015	0·69	0·23	0·43	1·37	0·04
280. Damaged blades from third, fourth and fifth stages. (Fig. 6)	586–589	0·39	0·037	0·009	0·67	0·20	3·32	0·82	None
	655–659	0·22	0·039	0·020	0·70	0·16	3·54	0·57	0·16
	706–709	0·35	0·042	0·022	0·74	0·22	3·21	0·79	None
Spare blades from all stages, from same lot as installed in 178 and 175. (Fig. 10)	711–750	0·39	0·043	0·016	0·73	0·26	0·39	1·33	None
	771–800	0·27	0·034	0·006	0·47	0·14	0·11	0·63	0·14
	801–814	0·40	0·046	0·018	0·59	0·27	2·99	0·75	0·14

	Monel.	Cu.	Ni.	Fe.	Mn.	Al.	C.	Si.
	710–720	27·86	69·15	1·99	0·62	1·89	0·16	0·09
	721–730	27·88	68·99	1·93	0·84	1·96	0·22	0·18

TABLE II.—Tension Test.

Vessel.	Material.	Blade No.	Original Section.	Test Length.	Section at Fracture.	Redn. Area.	Elongation.	Yield Point.	Tensile Strength.	Brinell Hardness.
			in.	in.	in.	per cent.	per cent.	lb. per sq. in.	lb. per sq. in.	
175	Chrome-Nickel	23–34	0·488×0·166	2	0·365×0·091	41·2	21·5	63,700	97,200	228
	Vanadium ..	70–75	0·479×0·099	1	0·355×0·066	50·7	28·0	60,300	94,700	228
	Chrome-Nickel	94–102	0·495×0·124	2	0·435×0·110	22·0	12·5	94,500	149,900	310
178	Do.	128–144	0·440×0·151	2	0·325×0·107	47·6	19·5	70,800	96,400	228
	Do.	147–158	0·514×0·128	2	0·386×0·095	44·4	20·5	73,300	98,200	241
280	Do.	306–318	0·429×0·077	1	0·335×0·060	39·1	24·0	87,900	110,900	269
	Do.	351–356	0·426×0·105	1	0·364×0·084	31·8	—	88,600	145,600	350

TABLE III.—Impact-Shear Tests.

Vessel.	As Received.				Heat Treated.			
	Material.	Specimen No.	Impact Values. Range.	Impact Values. Average.	Specimen No.	Heat Treatment.	Impact Values. Range.	Impact Values. Average.
280. Broken blades. (Fig. 7)	Chrome - nickel steel	381	32·4–33·4	32·7	385	E	29·7–29·2	29·4
		386	35·2–35·2	35·2				
		406	33·3–34·3	33·6				
		411	33·4–34·4	33·7				
280. "Burned" blades. (Fig. 7)	Do.	575	32·4–33·4	32·9	577	E	27·8–28·8	28·3
		546	33·3–34·3	33·5	548	C	29·7–30·2	29·8
		551	37·9–38·9	38·9	553	D	36·9–37·9	37·6
		560	37·4–37·9	37·7	562	C′	37·9–38·9	38·2
		541	38·8–39·8	39·1	543	D	39·2–40·2	39·7
		565	38·3–38·8	38·5	567	C′	29·7–30·2	29·8
		570	36·0–37·0	36·5	572	C′	30·1–30·1	30·1
		556	37·9–38·9	38·4	558	D′	28·7–28·7	28·7
280. Damaged blades. Third stage. (Fig. 4)	Do.	251	35·1–36·1	35·5	255	A′	24·0–24·5	24·3
		291	33·4–33·4	33·4				
		361–2	34·3–34·3	34·3				
"Brittle blades." (Fig. 8)	Cr-Ni-Van steel	501–3	29·7–30·2	29·8	505–6	E	36·0–37·0	36·5
		524–6	30·6–30·6	30·6	521–522	E	38·8–38·8	38·8
Monel blades	—	710	40·6	40·6				
		721	34·7–35·7	35·0				
Third stage. (Fig. 10) ..	Chrome-nickel steel	731	33·8–33·8	33·8				
		741	30·1–30·6	30·5	743	E	34·7–35·2	34·9
		751	35·1–36·1	35·6				
		761	32·9–33·4	33·1				
Fourth stage. (Fig. 10) ..	Cr-Ni-Van (0·11 Ni) steel	771	37·4–37·4	37·4				
		781	37·9–38·4	38·2	783	B′	24·5–25·0	24·6
		791	37·9–38·9	38·4	795	A	38·8–38·8	38·8
Fifth stage. (Fig. 10) ..	Cr-Ni-Van steel	801	32·4–33·4	32·9	803	E	30·6–31·6	31·1
Eccentric blade. (Fig. 9)	—	838	33·8–34·3	34·1				

Ni, and 0·1 per cent. to 0·3 per cent. Van. A notable departure from this classification occurs in the case of the blade from the fourth stage of the set of spare blades shown in Fig. 10. This contains 0·11 per cent. Ni, 0·63 per cent. Cr., and 0·14 per cent. Van.

The carbon content varies from 0·27 per cent. to 0·41 per cent. The sulphur content in most cases is rather high, approaching and in a few cases exceeding the limit of ·045 per cent. usually allowed for high-grade steel forgings. The phosphorus content varies within normal limits.

The chemical composition of the monel metal blades conforms to specifications excepting an excess of aluminium.

The significance of these results in relation to the causes of failure will be discussed later.

Discussion of Metallographic Examination.

The examination of the unetched surfaces of these blades shows in most cases little more than an average quantity of non-metallic inclusions. The grain structure was normal. One of the blades from the third stage of this set showed a very coarse non-uniform structure at the base of the blade, changing to small-grained and uniform at the ends. The structures of blades from fourth and fifth stages might be considered normal, excepting one blade, which gave evidence of overheating at the tip.

Discussion of Impact-Shear and Bend Results.

The impact-shear test results serve to give evidence of the possibilities of inducting brittleness in this class of steel. It is well known that an excessive degree of brittleness may be induced in chrome-nickel forgings by tempering under certain conditions, after hardening. There seems to be a critical temperature range in the vicinity of 550 deg. C. (1,022 deg. F.), which determines the effects of tempering treatments. After the initial quenching treatment, slow cooling from any temperature within the range 450 deg. C. to the transformation point

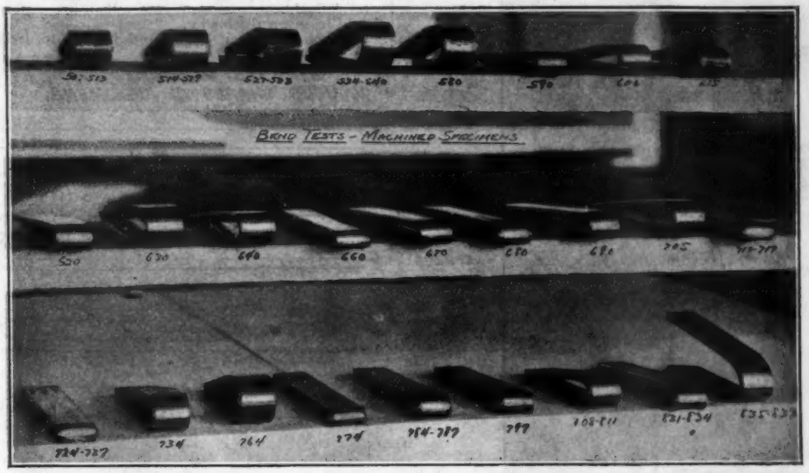

Fig. 11.

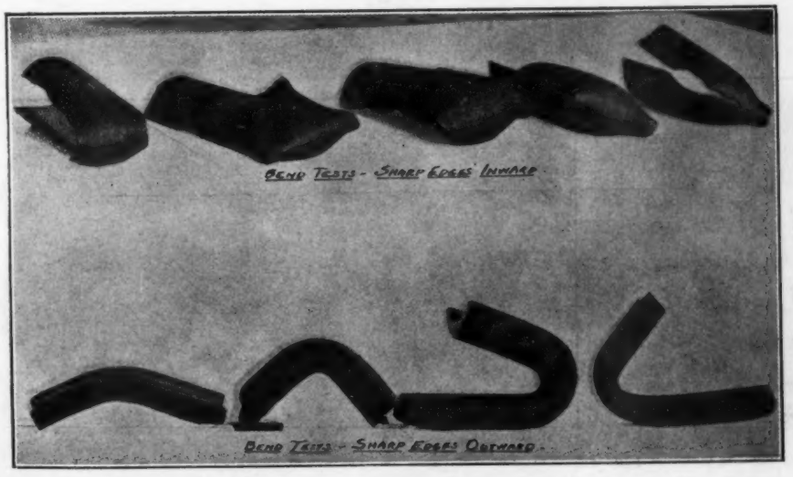

Fig. 12.

quantity of non-metallic inclusions, and these are well distributed throughout the metal.

The structures of blades from the 175 are all uniform, the grain size varying from moderate to fine.

Two of the blades from the 178 showed evidence of rapid cooling possibly followed by tempering. One of these showed a coarse triangular structure which is considered very undesirable. This structure was not found throughout the length of the blade, however, but only near the tip, and undoubtedly marks segregation of the alloying elements. The structure of the remaining blades is normal.

Nearly all of the blades from the 280 showed a uniform structure of moderate grain size. The two blades from the third and fourth stages respectively, which were broken while being installed, both showed a coarse grain structure near the break, merging to a small-grained structure at each end. The graduation from coarse to small-grained structure was quite uniform.

The monel metal blades from the first and second stages of the set of blades taken from the same lot as used in the 178 and 175, each contained an excessive temperature, may result in brittleness, the degree of brittleness increasing as the tempering temperature approaches the critical range at 550 deg. C. Quenching from 815 deg. C. (1,500 deg. F.) followed by rapid cooling from above 550 deg. C. to the Ac point will leave the metal tough; if followed by rapid cooling from any temperature between 450 deg. C. to 550 deg. C., will result in brittleness. The above remarks are based on tests made on chrome-nickel steels of the class known as "high chromium-nickel," containing about 3½ per cent. Ni, and 1½ per cent. Cr. The results obtained, as shown in Table III, bear out this discussion.

Consider first those specimens which were initially quenched from 815 deg. C. (1,500 deg. F.) and then given various tempering treatments. A comparison of impact-shear values of specimens from the same blades, before and after heat-treatment may be again summarised in Table IV.

The effects of simple annealing were variable, in some cases slightly increasing the impact-shear values, in other cases decreasing them slightly.

The bend tests on the blade material show that apparently in most cases the standard machined specimens could be bent through 180 deg. without signs of fracture. In some cases, failure after bending through approximately 180 deg. occurred. This shows that in general the material cannot be considered excessively brittle, although under certain conditions a slight tendency toward brittleness is indicated.

Table IV.—*Effects of Heat Treatments on Impact-Shear Tests.*

Treatment after Quenching from 815 Deg. C.	Impact-Shear Values.	
	Before Treatment.	After Treatment.
Slowly cooled from 520 deg. C. ..	35·5	24·3
Slowly cooled from 620 deg. C. ..	38·4	28·7
Rapidly cooled from 620 deg. C. ..	36·5	29·8
Rapidly cooled from 620 deg. C. ..	36·5	30·1
Rapidly cooled from 520 deg. C. ..	38·2	24·6

The bend tests on the blades as received, and the bend experiments on different shapes, throw light on the entire problem. It is a well-known fact that in a stressed bar containing a sudden change in cross-section, the distribution of stress is not uniform in the section where the change occurs. Under some conditions, the maximum stress may amount to considerably more than the average stress in that section. The design of this type of turbine blade is such that a sudden change of section occurs between the root and the blade body. This section is the one of maximum bending moment, and the maximum stress under bending would be considerably greater even than the theoretical stress. The shape of the blade section itself is very poorly suited to resisting bending loads without cracking. The sharp edges of the section are the points farthest removed from the neutral axis and therefore subjected to the greatest stress when the blade is bent. The bend experiments show that such a section when bent with the sharp edges outward will crack much more readily than one of rectangular shape. Thus, in Figs. 13 and 14, specimens A, having a rectangular section, bent completely through 180 deg. without cracking, excepting the one of Class "Ac" steel, which just cracked at 180 deg. A re-test of this specimen showed no crack. Specimens B with rectangular section, but bent at a sudden change of section also bent through 180 deg., excepting the "Ac" steel specimen which broke at 90 deg. The specimens C and D of turbine blade shape show cracks in every case. Those with the sudden change of section crack much sooner than those of uniform section.

The weakness of the turbine blade section is also brought out in Fig. 12. Turbine blade specimens bent with the sharp edges outward crack every time, in some cases after very slight bending. Those bent with the sharp edges inward in nearly every case bend completely through 180 deg. without signs of cracking, showing the inability of these sharp edges to undergo plastic deformation without cracking.

Discussing Probable Causes of Failure.

The significance of the results obtained in these tests may now be considered in relation to the probable causes of the failures of these turbine blades. The cause of any failure of an engineering material may be classified as due to either faulty material, faulty design, or improper operation. These will be discussed separately.

The great variation in the chemical analysis of the blades indicates in many cases a wide departure from the A.S.T.M. specifications for chrome-nickel steels. The preponderance of chromium over nickel found in the blades containing over 1 per cent. Cr. and about 0·5 per cent. Ni. is an unusual combination. Bullens, in "Steel and its Heat Treatment," states that ". . . . if the chrome content greatly exceeds a certain proportion in respect to nickel, the steel will be more difficult to heat-treat successfully, the temperature limits are more narrow, and the possibility of poor results is greatly increased. The best ratio is probably about 2½ parts nickel to 1 part chrome." It is notable that the A.S.T.M. specifications for chrome-nickel steel of different classes maintain approximately this ratio. However, the importance that may be attached to the variations of chemical analysis is minimised by the fact that failure occurred in the different sets apparently irrespective of chemical analysis.

It is well recognised that the forging of chrome-nickel steel must be carried on with great care to prevent the formation of fine surface cracks. Such cracks might easily be overlooked, and in turbine blades would develop rapidly, due to the fatigue stresses caused by vibration of the blades in service.

The question of vibration in turbines, causing fatigue failures of blades, has been given considerable attention, and many turbine failures have been attributed solely to that cause. The results of investigations at the Experiment Station have shown definitely that, under certain conditions, fatigue failures may be caused by stresses in the neighbourhood of half the elastic limit of the metal as determined by static tests. With reference to this point, attention is invited to the conditions that existed on the 280 previous to stripping.

Mention might also be made of such possible contributory causes as fouling of blades due to expansion of the rotor wheels with overspeed, fouling due to improper turbine adjustment or poor alignment of blades, the presence of foreign objects or the presence of excessive quantities of water. Investigations of these various failures showed conclusively that such conditions did not exist.

In the final analysis, the above are considered only possible contributory causes of these failures. The

heat treatment, bend and impact experiments show that although this material in most cases is ductile, in some cases a slight degree of brittleness was observed in the metal. As ordinarily tested, using standard machined bend specimens, the material would not be classed as excessively brittle. When the subject of blade design in relation to bending tests is considered, however, the dangerous condition which may result following bending the blades is brought out. The bend experiments show that when using a specimen closely approaching the actual turbine blade in shape, even a slight degree of bending is sufficient to form, at the base of the blade, slight cracks, even though the material itself may be inherently quite ductile.

In this connection the information given in the reports of the Commanding Officer of the *Vestal* is very significant. These reports speak of the difficulties experienced in blading the turbines due to variations from the standard very unusual composition, containing Cr. 0·63, Ni. 0·11, Van. 0·14. The composition of the monel metal blades from the first and second stages conforms to Navy specifications, excepting a slight excess of Al.

The metallographic examination showed considerable variation of structures typical of this grade of metal. In most cases the structure is quite satisfactory. In a number of cases the structure gives evidence of rapid cooling possibly followed by annealing. In other cases segregation of constituents was shown. In a few cases wide variations of structure between different parts of the same blade indicated lack of suitable annealing. However, nothing about the microstructure was considered sufficiently unusual to justify attributing the failures entirely to faulty metal.

The results of various heat-treatment, impact-shear and bend tests show that while in most cases this material is quite ductile, in some cases a slight brittleness in the paragraphs were based wholly upon the investigation carried out at the experiment station, they are borne out by many other facts of which the investigator had, at first, no knowledge. These other facts, while it is considered inadvisable to publish them here, have to do with the history of the blade material, the forging of the blades, the history of the assembly of rotor wheels for the various classes, the condition of spares, the inspection of the material and the kind of labour employed.

The excellence of the report of the investigation, which was carried on under the personal supervision of Mr. D. J. McAdam, Jr., cannot be too highly commented on.

While great care in turbine construction has always been an acknowledged necessity, attention is invited to the following :—

(*a*) In specifying the raw material consideration must be given to effect that subsequent forging will have on the material.

(*b*) Heat treatment, at whatever stage or stages it should take place, must be carefully watched.

(*c*) A final heat treatment, that will ensure uniformity should be given the blades.

(*d*) Each and every blade must be true to designed

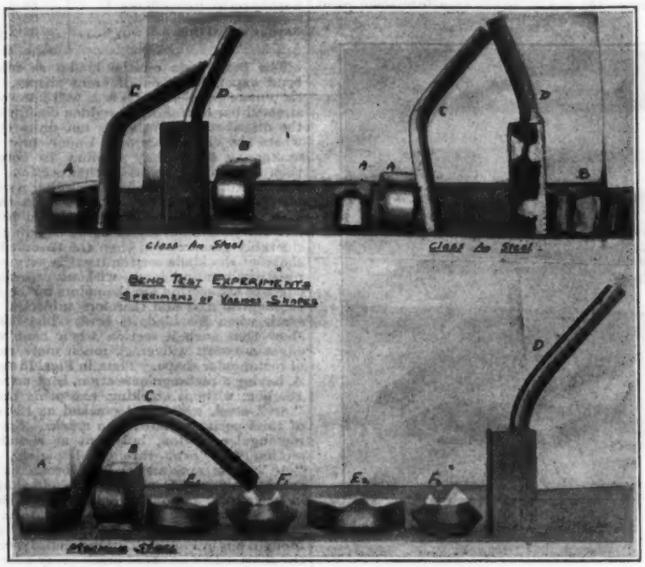

Fig. 13.

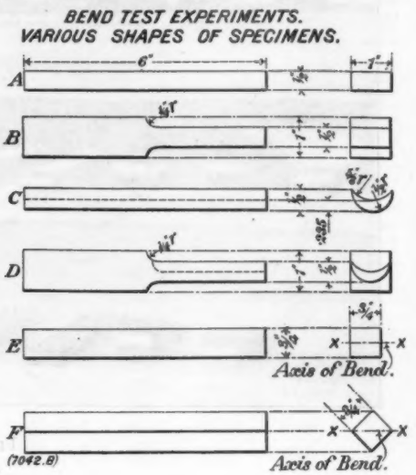

Fig. 14.

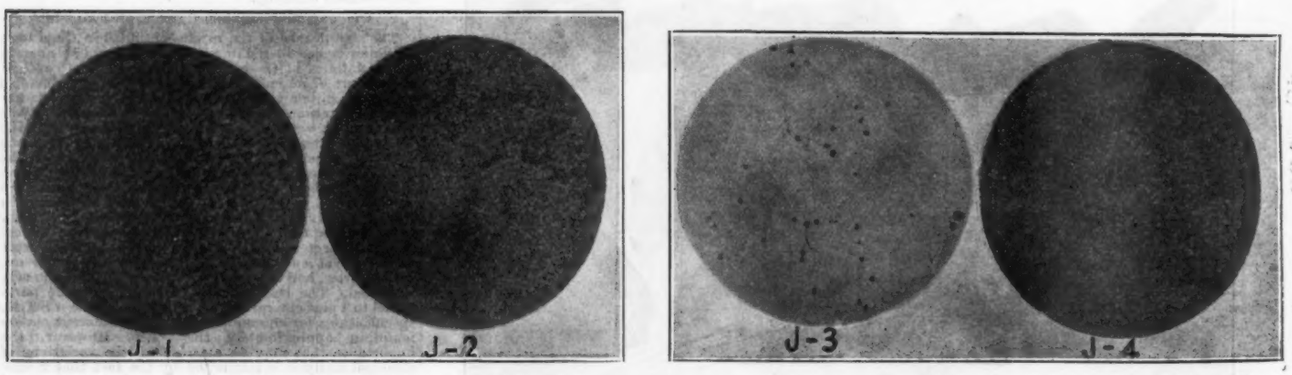

Fig. 15.

blade thickness and length, and due to lack of alignment between blades and shrouding. It was necessary to bend some of the blades considerably to fit them into the shrouding holes. This condition led to cracking some of the blades. In some cases the failure was complete as shown by the two blades in Fig. 8. In other cases the cracks were undoubtedly very small and easily overlooked. Stresses on the blade due to vibration in service would be concentrated at the base of such cracks, which would rapidly develop, and ultimately lead to failure and stripping. In this connection it must be remembered that it is necessary to break only one blade to cause stripping of an entire stage.

Conclusions.

Results of the chemical analysis of damaged blades from the 175 show these to be of chrome-nickel vanadium steel of the general composition Cr. 1·25 per cent., Ni. 0·40, Van. 0·20. The composition of the spare blade from the 175 indicates Cr. 0·70, Ni 3½, Van., none. The blades from the 178 are of the same composition as the 175 spare blade. The composition of the blades from the 280 varies, including both of the above types. One of the blades from the fourth stage of the 280 is of metal was observed. Under the worst conditions, however, the metal cannot be considered excessively brittle.

The results of the special bend experiments on specimens of various shapes, when studied in connection with information given regarding the difficulties encountered in blading these turbines, indicate with little doubt the cause of the whole trouble. The design of this type of turbine blade is such that it is very poorly fitted for undergoing plastic deformation when bent, without the formation of cracks at the junction of root and blade. While this is true even when the metal itself is very ductile, it is particularly true when there is a tendency to brittleness in the material due to faulty microstructure, or to other causes. In bending the blades to make them fit into the shrouding, a number of the blades cracked completely as stated in the reports of the Commanding Officer of the *Vestal* and as shown in Fig. 8. Undoubtedly many other blades were only cracked slightly, and these cracks passed unnoticed. Under the influence of service fatigue stresses, such cracks would rapidly develop, ultimately causing complete failure of the blade and stripping of the entire stage.

While the conclusions arrived at in the preceding shape; otherwise, in attempting to install, deformation of blade will take place.

(*e*) Under no circumstances should a bent blade be installed, nor should deformation of a blade, in order to make it fit, be attempted.

(*f*) The shroud band holes must be true with the tips of the blades, and to ensure this, after the blading is installed, a template should be made and from this the holes in the shroud band should be located.

(*g*) Every blade should be examined minutely, preferably with a glass, especially at the edges and around the root section, for cracks; if cracks are discernible the blade should be scrapped.

(*h*) The blades in question can be strengthened against cracking, to some extent, by allowing a larger fillet between the junction of the blade and the root and widening the sharp edges of the blade at the approaches to the root. Such, however, while it may tend to counteract defective workmanship, will not eliminate the possibility of failure due to deformation.

(*i*) Blades of good material, improperly manufactured, and mishandled during installation, are more likely to fail than blades of an inferior grade of material, properly manufactured and properly installed.